Report of The

SEA Research Planning Conference

on

Aquatic Weed Control

Davis, California

September 13-15, 1977

CONTENTS

Summary Report

Appendix

SUMMARY REPORT

I. EXECUTIVE SUMMARY

There is general agreement among water managers that aquatic weed problems are becoming more prevalent and more serious. Rapid eutrophication of water resources caused by increased urbanization, more intensive use of fertilizers, and greater use of available water, is commonly considered to be a major cause of the upward trend in severity of aquatic weed infestations. The introduction of several species of exceedingly noxious aquatic weeds from other areas of the world has added greatly to the weed problems and the need for research to develop control measures.

Irrigated agriculture is totally dependent upon an adequate and timely supply of good quality water for crop production. If aquatic and ditchbank weeds are not controlled, they reduce the supply and quality of water, reduce the effectiveness of water storage and distribution systems, prevent timely delivery of water, and lower agricultural production efficiency. In the 17 western states there are more than 173,000 miles of irrigation canals and ditches. In the 31 eastern states there are more than 190,000 miles of drainage ditches. Recent surveys show that algae and aquatic weeds cause serious problems in more than 60 percent of the 144,000 miles of irrigation canals.

In 1975, the direct losses to agriculture caused by aquatic and ditchbank weeds ammounted to $175 million. An estimated 2 million acre-feet of water are lost each year in the 17 western states because of these weeds. The net productive value of lost water amounted to more than $110 million per year. The Bureau of Reclamation spends approximately $6 million annually to control aquatic weeds in the water systems for which it has management responsibility. This represents an average cost of $145 per mile of canal for weed control or about 10 percent of the total operations and maintenance cost for these projects. The losses caused by weeds and the costs of their control on privately owned water systems are as great or greater.

There are more than 42 million acres of inland water in bodies of 40 acres or more. Current estimates indicate that 40 percent of this area is infested with nuisance levels of algae and aquatic weeds. Waterhyacinth and Hydrilla, two serious aquatic weeds, now infest over 1.2 million acres of water in Florida. These two species also cause serious damage and losses on more than 2 million acres in Louisiana, Texas, Mississippi, Alabama, Georgia, and California. Currently more than $25 million are being spent annually to control and prevent the spreading of these weeds. Recreation is one of the most important uses made of water in the United States. The Bureau of Sport Fisheries and Wildlife reported that for the year 1970, more than 80 million people spent well over 1.5 billion days in recreational activities involving the nations water resources. Fisherman alone spent over $5 billion dollars on sport fishing. Aquatic weeds are especially destructive of recreational water and hundreds of lakes have become unusable because of weed infestations.

In response to the needs of Federal and State Agencies with water management responsibilities, SEA/FR initiated research in the mid 1950's to develop new and improved methods for control of aquatic weeds. The technology developed permitted the substitution of herbicides for most of the costly mechanical control being practiced in irrigation systems, lakes and reservoirs, and on ditchbanks. Chemical control procedures were devised for weed infestations and aquatic sites not previously amenable to control. Research on biological control was conducted and several effective insects were introduced, evaluated, and released for control of alligatorweed. Despite the many advancements, much more progress must be made in developing an aquatic weed control technology that is adequate to solve present day problems.

Present control methods are based almost entirely upon chemical and mechanical methods. Some herbicides are not well adapted to aquatic uses because of cost, toxicity to fish, lack of specificity, toxicity to crops and other desirable plants, and possible hazards to the aquatic environment. Presently available technology includes effective and widely accepted biological control for only a single aquatic weed species. Much of weed control research is based on knowledge of the physiology, ecology, and biochemistry of the weed plants. Current aquatic weed control methods were developed with only a minimal amount of research data in these areas and there is little opportunity for employing integrated management techniques.

At the present time SEA/FR has 9.5 SY engaged in all aspects of research on control of aquatic weeds. This represents less than 1 percent of SEA/FR effort devoted to Plant Production Efficiency (Appendix Table 2 , page 21). State and other agencies, including Florida, Indiana, and Louisiana support the equivalent of approximately 5 full time SY. Most of these SY are involved in biological control with fish or plant pathogens. The distribution of research effort by SEA/FR scientists is as follows: biological control, 3.9 SY; fundamental research, 2.6 SY; chemical control, 2.8 SY; ecophysiology, 0.2 SY (Table 1, page 19).

This research planning conference provided an opportunity for SEA/FR scientists to confer with one another, and to exchange ideas with other research workers, administrators, and water managers from State and Federal Agencies concerning aquatic weed problems and research needs and priorities. After careful and thorough consideration, members of the several subcommittees recommended that high priority be given to increasing research in the following areas:

(1) Biological control. Add a total of 4.5 new SEA/FR SY at Davis, Fort Lauderdale, WRRC, and Prosser.

(2) Fundamental research. Add 11 SY to SEA/FR and 2 extramural SY. The new SY would be located at Denver, Stoneville, Davis, WRRC, Fargo, Fort Lauderdale, and Prosser.

(3) Chemical weed control. Add 10.2 new SEA/FR SY at Davis, Prosser, Fort Lauderdale, Denver, Stoneville.

(4) Ecophysiology of aquatic weeds. Add 3.3 new SEA/FR SY at Davis, Durant, Fort Lauderdale, and Prosser. In addition, 2 SY assigned by the Bureau of Reclamation to develop engineering technology to minimize weed problems.

(5) Mechanical control, harvesting and utilization of aquatic weeds. The University of Florida, Corps of Engineers, and the Bureau of Reclamation assign 27 SY to develop this technology in cooperation with SEA/FR.

It is hardly possible to identify anyone in society who will not benefit from this research effort in more plentiful and available supplies of water for agriculture, improved quality and greater quantity of potable water, enhanced property values, greater opportunity for the many kinds of recreational uses of water, and a more pleasing and aesthetically acceptable aquatic environment. There is no area of research that promises greater or more significant benefits to society for the funds invested. A conservative estimate of 10 percent reduction in problems and in losses caused by aquatic weeds would result in an estimated annual savings to agriculture of $17.5 million. Annual savings to the Bureau of Reclamation for weed control costs alone would be $600,000. State and Federal Agencies and private water management groups in Florida would save well over $2 million dollars annually in weed control costs. Benefits derived from the salvaged recreational and tourist industry are estimated to be even greater. It is apparent that the need for research and development of an adequate technology for aquatic weed control is broadly based. Support for a SEA research program to satisfy the need should be available from many different water management groups and agencies.

The subcommittee on Research Needs and Responsibilities concluded that current levels of support in funds and personnel are seriously inadequate to provide the new aquatic weed control technology required to meet current and future needs of government agencies and the public. In addition, the following specific recommendations were made. Greater use should be made of Memorandums of Understanding to foster cooperation and coordination of effort among State Agencies, Federal Agencies, and private and public groups. A lead agency concept should be established by Federal Agencies in which a specific agency undertakes those tasks compatible with the agency mission, personnel, facilities, and other resources.

There is serious need for Federal Agencies and other groups to coordinate and support requests to departmental budget officers and the Office of Management and Budget regarding financial support and manpower for aquatic weed control research. Research staffs should consist of a disciplinary mix of scientists to permit a broader approach to the very complex research problems. Priority should be given to more extensive staffing of one research location in the southeast (Ft. Lauderdale) and one location in the west (Davis). There are few herbicides registered for aquatic uses. SEA/FR must become more concerned with the development of data on toxicity and environmental safety, and encourage greater acceptance of aquatic herbicides in the IR-4 Program. As personnel ceilings become more restricitve, SEA/FR finds it exceedingly difficult to cooperate with user agencies by performing research of mutual interest. Consequently, representatives of Federal Agencies involved should explore with the Office of Management and Budget the provision of additional positions for SEA/FR scientists and technicians engaged in aquatic weed control research with regular funds and funds provided by user agencies.

II. RECOMMENDATIONS OF THE SUBCOMMITTEES [1/]

A. Subcommittee on Research Needs and Responsibilities

The subcommittee concluded that current levels of research and research funding and personnel are seriously inadequate to provide the new aquatic weed control technology required to meet current and future needs of government agencies and the public.

It was recommended that:

1. The aquatic weed control research and related activities of SEA and other Federal and State Agencies be better coordinated to establish research priorities and to avoid unnecessary duplication of effort.

2. Greater use be made of Memorandums of Understanding to develop a broad base of cooperation and united effort among agencies such as SEA, TVA, Bureau of Reclamation, Corps of Engineers, Fish and Wildlife Service, and others. This cooperative arrangement would eventually include participation by APHIS, SCS, and EPA. Some mechanisms should be developed for participation and involvement of state water management agencies and local and private interests.

3. A lead agency research concept should be established in which a specific agency would undertake those tasks that are compatible with its overall mission, personnel, and facilities.

4. SEA should be concerned primarily with basic and developmental mission oriented research on the various approaches to aquatic weed control. Agencies with water and land management responsibilities should emphasize advanced field testing and pilot applications to corroborate data on efficacy and environmental effects, to develop additional data to support registration, and undertake control and eradication measures. The divisions of responsibilities should be developed through mutually agreeable arrangements set forth in the Memorandums of Understanding.

5. Federal Agencies and other groups coordinate and support budget requests and proposals for financial support and manpower for aquatic weed control research.

6. Present research locations should be adequately staffed and funded prior to establishment of additional research locations.

7. Research staffs should consist of a disciplinary mix of plant physiologists, botanists, soil scientists, chemists, aquatic

[1/] Recommendations are listed in order of priority within each subcommittee report.

biologists, agricultural engineers, and others, to conform with the principal goals and objectives of the location. Since funding and staffing research locations will require some time, it was recommended that two locations, one in the southeast (Ft. Lauderdale, Florida) and one in the west (Davis, California) be expanded initially to utilize the multidisciplinary research approach.

8. SEA should become more concerned with the development of data on toxicity and environmental safety of promising aquatic herbicides in order to hasten use registration by EPA.

9. Greater effort has to be made to encourage acceptance of aquatic herbicides as minor use pesticides in the IR-4 Program.

10. Representatives of the Federal Agencies should explore with the Office of Management and Budget the establishement of a category of personnel assignments for use by SEA in conducting research needed by user agencies with funds provided by these agencies. The new category of personnel would not conflict with current SEA employee ceilings.

11. An accurate and comprehensive survey be made to determine the nature and extent of aquatic weed problems, and the losses caused by the weeds to industry, agriculture, and society at large. It was recommended that a mechanism for such a survey be devised and that a comprehensive, authentic, and credible survey be insured by participation of the Economic Statistics and Cooperative Service and other agencies experienced and qualified to carry out such studies.

12. SEA and other Federal Agencies should encourage and promote training of future weed scientists through support of research by state universities and agricultural experiment stations, and by private institutions.

B. Subcommittee on Biological Control

The subcommittee recognized that biological control should have an important and major role in the development of an integrated pest management system for control of aquatic weeds. Because of its effectiveness, economy, and minimal detrimental effect on the environment, biological control should form the basis for future management systems.

To achieve this objective, the subcommittee recommended that:

1. Methods be developed for implementation and utilization of natural enemies of aquatic weeds by practices such as: periodic inundative releases of insects, pathogens, herbivorous fish, and competitive plants; control of natural parasites of the natural enemies; and inducing attacks by natural

enemies by modifying the mechanisms of natural resistance of the host plants.

SEA has no present SY assignment in this area of research. No SY are recommended specifically for these investigations which will be conducted by scientists assigned to recommendations 2 and 3 below.

2. Surveys be conducted to identify foreign and indigenous pathogens, insects, and other plants and animals that have potential value as biological agents for control of aquatic and ditchbank weeds.

   SEA currently has 2.2 SY engaged in this research. It is recommended that an additional 5 SY be assigned to this area of research and that they be located as follows: 1 microbiologist at Davis, 1 plant pathologist and 3 entomologists at Fort Lauderdale.

3. Modes of action of natural enemies in controlling aquatic weeds, and the environmental and habitat requirements of natural enemies be investigated; and the impact of control agents on the aquatic environment determined.

   Current SEA research effort on the above research is 1.7 SY. An additional 3.5 SY are recommended for Davis (1 SY), Ft. Lauderdale (1 SY), and Western Regional Research Center (WRRC) (1.5 SY).

4. A plant search, evaluation, and breeding program be initiated to select and develop desirable species to replace those currently causing problems in aquatic and ditchbank sites.

   SEA has no research effort in this area. It is recommended that 1 SY be added for this research at Prosser.

C. Subcommittee on Fundamental Research

The subcommittee cited the strong need for fundamental research which is recognized as the basis for new concepts and approaches to weed control. Technological development is advanced more rapidly when an adequate reservoir of fundamental research data is available.

The subcommittee concluded that there was serious need for more fundamental research on aquatic weeds and recommended that:

1. Additional research be devoted to life histories, reproductive and stress physiology, and the growth and morphogenesis of aquatic weeds. Special consideration should be given to the function and role of endogenous growth regulators, physiology and dormancy of perennating organs, photomorphogenesis, and senescence.

   Present SEA research effort is 0.8 SY. A total of 5 SY of effort is recommended to meet present needs (Stoneville 1 or 2 SY, Denver 1 or 2 SY, Davis 1 SY, and WRRC 1 SY).

2. Research be expanded on photosynthesis, respiration, and metabolism of aquatic plants with emphasis on carbon sources, photorespiration, gas exchange, and production and release of metabolites into the aquatic habitat.

SEA currently devotes 0.3 SY to this basic research. A total of 3 SY is recommended to meet present and future needs (Fargo 1 SY, Extramural 2 SY).

3. The uptake, translocation, and exchange of nutrients by aquatic plants be investigated. Examine the role of biologically active organic compounds produced by bacteria, fungi, and other plants in the establishment, growth, and reproduction of aquatic weeds. Determine the nutritional requirements of aquatic weeds, establish the toxic and deficiency levels of nutrients, and the role of water chemistry and nutrient cycling in aquatic habitats. Identify and quantify the mineral and organic constituents of the principal species of aquatic weeds considered to be amenable to mechanical control, harvesting, and utilization.

   Current SEA research in this area is 1.5 SY. It is recommended that this effort be expanded to a total of 7 SY at Davis (2 SY), Denver (1 SY), Fort Lauderdale (1 SY), Stoneville (1 SY), Prosser (1 SY), and Extramural (1 SY).

D. Subcommittee on Chemical Weed Control

The subcommittee on chemical control concluded that herbicice use will always be an important segment of management systems designed for control of aquatic and ditchbank weeds. Herbicides are an important adjunct to several current approaches to biological control, including the use of herbivorous fish and competitive vegetation. Integrated pest management systems for aquatic and ditchbank weed will frequently involve initial and periodic supplemental treatment of weeds with herbicides.

In view of the present and future need for aquatic herbicides, the subcommittee made the following recommendations:

1. Develop less costly, highly specific, highly selective, and environmentally safe aquatic and ditchbank herbicices by improving evaluation techniques and expanding the sources of experimental compounds. Devise effective mixtures of herbicides or herbicides and growth regulating compounds for specific weeds and sites, and where possible, incorporate the use of herbicides in weed management systems.

   At the present, SEA effort on this research is 1.7 SY. It is recommended that it be increased to 3 SY to meet current and future needs (Davis 1 SY, Prosser 0.5 SY, Fort Lauderdale 1.5 SY).

2. Investigate the relationships between aquatic herbicides and the physical and chemical parameters of aquatic habitats as they relate to herbicide efficacy and toxicity to non-target organisms. Promote registration and safe use of aquatic herbicides by establishing the levels of residues and their persistence in irrigation water, determine the fate of herbi-

cides in water and ditchbank soils, and devise methods to remove or deactivate when necessary the herbicide residues in aquatic sites.

SEA currently expends 1.1 SY on this research. It is recommended that it be increased to 5 SY to meet present and future needs (Prosser 1 SY, Denver .4 SY, Ft. Lauderdale 1 SY, Davis 1 SY, Stoneville 1.3 SY).

3. Develop more accurate and effective equipment and techniques for herbicide applications, obtaining water and soil samples, and making estimates of aquatic weed biomass.

   SEA at present has no research effort in this area. It is recommended that 2 SY be assigned to this research (Ft. Lauderdale 1 SY, Extramural 1 SY).

E. Subcommittee on Ecophysiology of Aquatic and Amphibious Weeds

Ecophysiology is one of the most fundamental areas of study for determining the factors that are responsible for the distribution, population densities, succession, and species interactions of natural plant communities. Because ecophysiological data are basic to interpretation of the behavior and responses of plants to their habitat, the subcommittee concluded that research in this area was vitally important.

The subcommittee recommended that:

1. Research be conducted on plant successions, species interactions (including competition and allelopathic effects), and the responses of aquatic weeds to sedimentation, agricultural runoff water, and soil types. Strong emphasis should be placed on initial establishment of desirable species following construction of water-holding facilities and the development of data to allow prediction of sequences of species reappearance after the use of weed control practices.

   At present SEA has 0.2 SY of research on ecophysiology. It is recommended that a total of 3.5 SY be assigned to this research to satisfy future needs (Davis 1 SY, Durant 1 SY, Ft. Lauderdale 1 SY, Prosser 0.5 SY).

2. Engineering technology be developed to minimize weed problems through improved design of water impoundments, and water transport systems such as dual systems of ponds or canals.

   SEA expends no SY on this research. It is recommended that the Bureau of Reclamation assign 2 SY to this area of research.

3. A nationwide survey be made to develop an accurate and current assessment of the distribution of aquatic weeds, the extent and nature of the weed problems, the losses engendered by the weed infestations, and the overall effects of weeds on national water needs and uses. The subcommittee concluded that the survey is urgently needed to provide the basis for establishing and funding research programs, inducement to industry to invest in research and developmental work in aquatic weed control, and to provide a baseline for future assessments of aquatic weed problems. It is recommended that an attempt be made to survey 10 states each year with a commitment of 0.5 SY per state. This survey seems suited to a collaborative effort among various agencies and should include ESCS, Extension Service, Statistical Reporting Service, Cooperative State Research Service, and others.

   At the present time, SEA has no effort in this area of work.

F. Subcommittee on Mechanical Control, Harvesting, and Utilization

Various mechanical methods were used for control of aquatic weeds before herbicides were commonly available. In recent years there has been a resurgence of interest in mechanical control because of the absence of appropriate herbicides; more stringent restrictions involving the use of herbicides, and interest in the harvest and utilization of aquatic weeds as a renewable resource. The subcommittee concluded that mechanical control, and harvesting and utilization, would likely become more prominent and should have an important role in management systems for aquatic weed control.

In order to initiate a meaningful research program in this area, the subcommittee recommended that:

1. An operational aquatic weed harvesting system be constructed for testing under a variety of conditions to collect data to develop and/or verify portions of a mechanical model and to determine the economic feasibility of mechanical control.

   There is no SEA research effort in this area. It is recommended that 10 SY be assigned to this project to satisfy present and future needs for research on mechanical control and utilization of aquatic weeds (Corps of Engineers, Bureau of Reclamation, University, other).

2. Research be conducted to develop data on the importance of weed density, dimensions, strength, and deformation characteristics (sheer,tension, compression) in situ and under a range of conditions for determining the requirements of harvesters and related components of the total system.

SEA devotes no SY to this area of study at the present time. It is recommended the 2 SY be assigned to this research (Corps of Engineers, University, Extramural).

3. An integrated mathematical model of aquatic ecosystems be developed that can be used to design and evaluate operational scale chemical, biological, mechanical, environmental manipulations, and integrated aquatic weed management systems for any species of weed or site.

   At the present time, SEA has no research effort in this area. It is recommended that 10 SY be assigned to this task (Corps of Engineers, University of Florida, Extramural, other).

4. New and versatile equipment be designed and constructed for mechanical control of aquatic and ditchbank weeds in and along irrigation canals and drainage ditches.

   Currently SEA has no SY assigned to this work. It is recommended that 5 SY be devoted to this area of research to satisfy present and future needs (Bureau of Reclamation, SEA, University, other).

Return to:

LF FORM 516 (6-78)

U.S. Department of Agriculture
Science & Education Administration
National Agricultural Library
Lending Division
Beltsville, Maryland 20705

Reference begins on

Page ____________

Return publication with this slip bottom end up.

For renewal and/or transfer of publication call (301) 344-3761.

DUE

TO: Marc C. Bruner
USDA-SEA/AR SR
3205 S.W. 70th Ave
Ft. Lauderdale, FL.
33314

TABLE 1
Current Locations of SY and Distribution of Research Effort Among SEA Scientists in Aquatic Weed Control

Locations	SY Biological control	Fundamental research	Chemical control	Eco-physiology	Mechanical control	Totals
Davis	0.9	0.4	0.7	-	-	2.0
Denver	-	0.4	0.6	-	-	1.0
Ft. Lauderdale	1	0.3	0.7	-	-	2.0
Gainesville	1	-	-	-	-	1.0
Prosser	0.4	0.8	0.8	-	-	2.0
Stoneville	0.3	0.5	-	0.2	-	1.0
WRRC	0.3	0.2	-	-	-	0.5
Total	3.9	2.6	2.8	0.2	0	9.5

TABLE 2

SUMMARY OF CURRENT AND RECOMMENDED STAFFING FOR RESEARCH ON CONTROL OF AQUATIC WEEDS

		Additional SY Recommended						
Locations	SEA current SY	Biol control	Fund research	Chem control	Eco physical	Mech control	Add SY recommended	Total SY current and recommended
Davis, CA	2	2	2.6	1.3	1	-	6.9	8.9
Denver, CO	1	-	1.6	0.4	-	-	2	3
Durant, OK	-	-	-	-	1	-	1	1
Fargo, ND	-	-	1	-	-	-	1	1
Ft. Lauderdale, FL	2	3.5	1.7	2.2	1	-	8.4	10.4
Gainesville, FL	1	1	1.2	-	-	-	2.2	3.2
Prosser, WA	2	1	-	1.2	0.5	-	2.7	4.7
Stoneville, MS	1	1	1.5	1	-	-	2.7	4.5
WRRC, Albany, CA	0.5	1.5	1	-	-	-	2.5	3.0
Extramural 1/	-	-	2	1	-	-	3	3
Total Current SEA	9.5							
Recommended increase		10	12.6	7.1	3.5	0	33.2	
Total recommended SEA	9.5						33.2	42.7
SY Recommended For Other Agencies								
Bureau of Reclamation	-	-	-	-	2	-	2	2
Other 2/	-	-	-	-	-	27	27	27

1/ Locations not specified.
2/ Recommended 27 SY for research and developmental work on mechanical control, harvesting, and utilization of aquatic weeds. Work to be undertaken by Corps of Engineers, Bureau of Reclamation, Univ. of Florida, and other Universities and agencies.

THE RESEARCH PLANNING CONFERENCE ON AQUATIC WEED CONTROL

The Research Planning Conference was held at Davis, California, during the period September 13-15, 1977. The conference was attended by the SEA scientists presently involved in research on control of aquatic weeds. Others attending the conference for SEA were: W.C. Shaw and J. Lunin, Staff Scientists, National Program Staff; R.L. Olson, PPR, Western Region; Area Directors P.H. van Schaik, E.B. Knipling, D.F. Davis, and S.N. Brooks; Assistant Area Director J.M. Vetterling, and A.I. Morgan, Jr., Director of WRRC. L.A. Andres, Biological Control of Weeds Laboratory, Albany, CA, and R.G. Menzel, Water Quality Control Laboratory, Durant Oklahoma, also of SEA, and L.O. Bagnall, University of Florida contributed to the conference in their areas of expertise. Because of the extent and seriousness of aquatic weed problems, intense interest in the conference was shown by numerous State and Federal Government Agencies and private groups. A number of representatives of these agencies and groups attended and contributed extensively in the research planning.

The objectives of the Research Planning Conference were to:

1. Assess the magnitude of the aquatic weed problems and the losses they cause.

2. Estimate the impact of aquatic weeds on agriculture, recreation, domestic water supplies, and other water users.

3. Evaluate the progress and effectiveness of current research in solving aquatic weed problems.

4. Determine the present and future needs for research by SEA/FR to support the operational programs of Federal Agencies who develop or manage water resources, other water users, and to meet the needs of the Agricultural Experiment Stations and other agencies.

The participants (see attendance list pages 15-18), including representatives of groups and agencies having water management responsibility, reviewed the major aquatic weed problems, past and present research programs and accomplishments, and deficiencies in currently available aquatic weed control technology and research programs. Intensive discussion and planning were channeled into 6 areas of research and other needs. The areas covered were:

1. Biological control.

2. Chemical control.

3. Mechanical control, harvesting and utilization.

4. Ecology and eutrophication of water.

5. Fundamental research.

6. Research needs and responsibilities.

Each of these research areas was examined as to current status, importance in comprehensive research programs, deficiencies, funding and staffing needs, and research priorities.

At present SEA allots about 9.5 SY and about $950,000 for research on control of aquatic weeds nationwide. This is approximately 18% of the total funds expended for all weed control research. The effort devoted to aquatic weed control by SEA is inadequate to solve the present problems or to cope with future problems arising from the spreading of endemic species and the exotic species already present in the United States.

SEA has, up to present, conducted most of the research on aquatic weed control. Very few states, now or in the past, have devoted any research effort in this area. The State of Florida, within recent years and largely as a consequence of serious problems with the weed hydrilla, has assigned several scientists to investigate the biological control of several aquatic weeds.

SEA/FR scientists have played a major role in developing the technology currently employed in control of aquatic plants. Many of the aquatic herbicides now being used were discovered and developed largely by SEA workers. It is recognized in a number of the Western States that, without the chemical procedures devised by SEA scientists and Bureau of Reclamation cooperators for control of weeds in irrigation canals, half of the farmers would be without water by the middle of every growing season. However, it is also recognized that some of the herbicides used are not ideal and, because of severe effects on aquatic organisms, must be replaced by less hazardous herbicides or other control measures.

The scientists, water managers, administrators, and others present with strong interests in aquatic weed control, discussed the many research problems and needs and developed recommendations for future SEA research.

List of Pariticipants in the Aquatic Weed Control Research Planning Conference Davis, California - September 13-15, 1977

SCIENCE AND EDUCATION ADMINISTRATION

* Dr. Lars Anderson, Research Leader
Plant Physiologist
Aquatic Weed Research Laboratory
Denver Federal Center
P. O. Box 25007
Denver, Colorado 80225

Dr. Lloyd Andres, Research Leader
Research Entomologist
University of California, Gill Tract
1050 San Pablo Avenue
Albany, California 94706

Mr. Stanley R. Bissell
Soil Scientist
USDA-SEA/FR
Aquatic Weed Control Facility
University of California
Davis, California 95616

Dr. S.N. Brooks, Area Director
Washington-Oregon Area
USDA-SEA/FR
219 Agricultural Science, Phase II
Washington State University
Pullman, Washington 99163

Dr. G. Buckingham, Entomologist
Insect Enemies of Aquatic Weeds
Research Laboratory, USDA
P. O. Box 1269
Gainesville, Florida 32602

* Dr. T.D. Center, Entomologist
USDA-SEA/FR
Aquatic Plant Mgt. Laboratory
3205 S.W. 70th Avenue
Fort Lauderdale, Florida 33314

* Dr. Richard D. Comes
Plant Physiologist
P. O. Box 30
Irrigated Agric. Res. and
Extension Center
Prosser, Washington 99350

Dr. H.C. Cox, Deputy Administrator
USDA-SEA, Western Region
2850 Telegraph Avenue
Berkeley, California 94705

Dr. Dean F. Davis, Area Director
Florida-Antilles Area
USDA-SEA/FR
P. O. Box 14565
Gainesville, Florida 32604

Mr. Nathan Dechoretz, Biologist
USDA-SEA/FR
Aquatic Weed Control Facility
University of California
Davis, California 95616

* Dr. Peter A. Frank, Research Leader
Plant Physiologist
USDA-SEA/FR
Botany Department
University of California
Davis, California 95616

Dr. Richard H. Hodgson
Plant Physiologist
USDA-SEA/FR
Metabolism and Radiation Research Lab
State University Station
Fargo, North Dakota 58102

Dr. E.B. Knipling, Area Director
California-Hawaii-Nevada
USDA-SEA/FR
P. O. Box 8143
Fresno, CA 93727

Dr. J. Lunin, Staff Scientist
National Program Staff
Environmental Quality
Room 233A, B-005
BARC-West
Beltsville, Maryland 20705

* Dr. Louis Marquis
Plant Physiologist
USDA-SEA/FR
Irrigated Agriculture Research
and Extension Center
Prosser, Washington 99350

Dr. Ronald G. Menzel, Research Leader
USDA-SEA/FR
Route 2, Box 322A
Water Quality Mgt. Laboratory
Durant, Oklahoma 74701

Dr. Arthur I. Morgan, Jr.
Center Director
Western Regional Research Center
USDA-SEA/FR
Berkeley, California 94710

Dr. R.L. Olson, PPR
USDA-SEA/FR
Western Region
2850 Telegraph Avenue
Berkeley, California 94705

* Dr. P.C. Quimby
Plant Physiologist
USDA-SEA/FR
P. O. Box 225
Southern Weed Science Laboratory
Stoneville, Mississippi 38776

Dr. W.C. Shaw, Staff Scientist
National Program Staff
Plant & Entomological Sciences
USDA-SEA/FR
Agricultural Res. Center-West
Beltsville, MD 20705

* Dr. Ken L. Stevens
Natural Products Chemistry
Western Regional Research Center
USDA-SEA/FR
800 Buchanan Street
Berkeley, CA 94710

Dr. Peter H. van Schaik
Assist. Area Director
California-Hawaii-Nevada
USDA-SEA/FR
P. O. Box 8143
Fresno, CA 93727

* Dr. K.K. Steward, Research Leader
Plant Physiologist
USDA-SEA/FR
Aquatic Plant Mgt. Laboratory
3205 S.W. 70th Avenue
Fort Lauderdale, Florida 33314

Dr. John M. Vetterling
Assistant Area Director
Colorado-Wyoming Area
USDA-SEA/FR
P. O. Box E
Fort Collins, Colorado 80522

* Dr. Richard R. Yeo, Botanist
USDA-SEA/FR
Botany Department
University of California
Davis, CA 95616

ENVIRONMENTAL PROTECTION AGENCY

Dr. Robert Hummel
EPA, Office of Pesticide Programs
Registration Division
Chemistry Branch
Washington, D.C. 20460

EXTENSION SERVICE

Dr. Fred E. Westbrook, Agronomist
Extension Weed Specialist
Extension Service
U. S. Dept. of Agriculture
Washington, D.C. 20250

SOIL CONSERVATION SERVICE

Mr. Wendell Miller
Soil Conservation Service
California Office
2828 Chiles Road
Davis, CA 95616

U. S. ARMY CORPS OF ENGINEERS

Mr. W.M. Rushing, Research Botanist
Aquatic Plant Research Branch
U.S. Army Corps of Engineers
Waterways Experiment Station
P. O. Box 631
Vicksburg, Mississippi 39180

U.S. FISH AND WILDLIFE SERVICE

Mr. Bernard L. Berger
Registration Liaison
Division of Population Regulation Research
Fish and Wildlife Service
Washington, D.C. 20240

Mr. Tom Jackson
Fish and Wildlife Service
Denver Field Research Station
Code 1522 B
Box 25007, Denver Federal Center
Denver, Colorado 80225

TENNESSEE VALLEY AUTHORITY

Mr. A. Leon Bates
Water Quality and Ecology Branch
TVA, E and D Building
Muscle Shoals, Alabama 35660

BUREAU OF RECLAMATION

G.W. Hansen
Pesticide Specialist
USBR- Code 410
Denver Federal Center
P. O. Box 25007
Denver, Colorado 80225

Mr. N.E. Otto, Head Environmental Sciences Section
P. O. Box 25007
Denver Federal Center
Denver, Colorado 80225

Mr. Thomas H. Seldon
U.S. Dept. of Agriculture
Bureau of Reclamation
Division of Water and Land
Washington, D.C. 20240

Mr. Carl Tennis
U. S. Dept. of Interior
Bureau of Reclamation
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, CA 95825

Mr. W. Wilson
U.S. Dept. of Interior
Bureau of Reclamation
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, CA 95825

CALIFORNIA DEPT. OF FISH AND GAME

Dr. George McCammon, Chief
Inland Fisheries Branch
California Dept. of Fish and Game
1416 9th Street
Sacramento, CA 95814

CALIFORNIA DEPT. OF FOOD AND AGRICULTURE

Mr. Carl Nichols
Division of Plant Industry
Dept. of Food and Agriculture
1220 N Street
Sacramento, CA 95814

Mr. Robert Roberson
Assistant Director
Division of Plant Industry
Dept. of Food and Agriculture
1220 N Street
Sacramento, CA 95814

CALIFORNIA DEPT. OF PUBLIC HEALTH

Dr. Alice Ottoboni, Toxicologist
Dept. of Public Health
2151 Berkeley Way
Berkeley, CA 94704

CALIFORNIA DEPT. OF WATER RESOURCES

Mr. Albert J. Dolcini
District Chief - Northern District
California Dept. of Water Resources
P. O. Box 607
Red Bluff, CA 96080

Mr. Warren V. Johnson
Weed Specialist
Rm. 1604 - Resources Bldg.
California Dept. of Water Resources
1416 9th Street
Sacramento, CA 95814

Mr. Leo D. Moyer
Division of Planning
California Dept. of Water Resources
1450 Riverbank Road
Sacramento, CA 95814

Mr. Glen Rothrock, Biologist
California Dept. of Water Resources
Water Quality Section
P. O. Box 388
Sacramento, CA 95802

PURDUE UNIVERSITY

Dr. Carole A. Lembi
Dept of Botany and Plant Path.
Lilly Hall of Science
Purdue University
Lafayette, Indiana 47907

UNIVERSITY OF CALIFORNIA

Dr. Floyd M. Ashton
Professor and Botanist
Botany Department
University of California
Davis, CA 95616

Dr. David E. Bayer
Professor and Botanist
Botany Department
University of California
Davis, CA 95616

Dr. Ernest M. Gifford, Jr., Chairman
Botany Department
University of California
Davis, CA 95616

UNIVERSITY OF FLORIDA

Dr. Larry Bagnall
Dept of Agricultural Engineergin
University of Florida
Gainesville, Florida

Dr. T.E. Freeman, Plant Pathologist
Diseases and Pathogens of Water Weeds
Dept. of Plant Pathology
University of Florida
Gainesville, Florida 32611

INDUSTRY

Mr, John E. Gallagher
Research and Development
Amchem Products, Inc.
Ambler, Pennsylvania 19002

WATER AGENCIES

Mr. Robert T. Durbrow, Consultant
Association of California Water Agencies
1127 11th Street, Suite 305
Sacramento, CA 95814

Mr. Bob Gates, Director
Field Operations
Southwest Florida Water Management District
5060 U.S. Highway 41 South
Brooksville, Florida 33512

* SEA Scientists engaged in aquatic weed control.

APPENDIX

TABLE 1

Detailed Classification Summary: NRP 20280 Weed Control Technology
Research As of 12/77

Activity	Commodity	Science	RPA	Work Unit	ARS Funding	SY	Other Funding	SY
4700 Weeds	0200 Water	0112 Biochem	105	7402-20280-005	$ 7,500	0.1		
4700 Weeds	0200 Water	0212 Biology-Env	105	7402-20280-005	52,000	0.7		
4700 Weeds	0200 Water	0412 Entomology	105	7402-20280-005	15,000	0.2		
4700 Weeds	0200 Water	0412 Entomology	105	7615-20280-005	46,578	0.4	49,262	0.4
4700 Weeds	0200 Water	0212 Biology-Env	105	7615-20280-005	11,645	0.1	12,315	0.1
4700 Weeds	0200 Water	1312 Physiology	901	5604-20280-001	10,200	0.1	4,300	0.05
4700 Weeds	0200 Water	0912 Nutrition	901	5604-20280-001	14,400	0.15		
4700 Weeds	0200 Water	1524 Chem-Anal	318	5604-20280-001			6.200	0.05
4700 Weeds	3950 Irrigate	1524 Chem-Anal	901	5604-20280-001	4,900	0.05		
4700 Weeds	3950 Irrigate	1312 Physiology	318	5604-20280-001	4,900	0.05		
4700 Weeds	0200 Water	0112 Biochem	318	5604-20280-002	9,000	0.1		
4700 Weeds	0200 Water	1312 Physiology	318	5604-20280-002	18,000	0.1		
4700 Weeds	0200 Water	0212 Biology-Env	901	5604-20280-002	9,000	0.05		
4700 Weeds	0200 Water	1524 Chem-Anal	318	5604-20280-002			9,000	0.1
4700 Weeds	3950 Irrigate	1312 Physiology	901	5604-20280-002	5,600	0.05		
4700 Weeds	3950 Irrigate	0212 Biology-Env	901	5604-20280-002	5,600	0.05		
4700 Weeds	0200 Water	0212 Biology-Env	901	5604-20280-003				
4700 Weeds	0200 Water	1524 Chem-Anal	701	5604-20280-003	5,600	0.05		
4700 Weeds	3950 Irrigate	0212 Biology-Env	901	5604-20280-003				
4700 Weeds	0200 Water	0212 Biology-Env	105	5806-20280-001	34,400	0.6		
4700 Weeds	0200 Water	1312 Physiology	105	5806-20280-001	11,500	0.2		
4700 Weeds	0200 Water	0212 Biology-Env	105	5806-20280-004	6,600	0.15		
4700 Weeds	0200 Water	1312 Physiology	105	5806-20280-004	15,400	0.35		
4700 Weeds	0200 Water	0210 Physiology	105	5206-20280-001	9,000	0.1	10,000	0.1
4700 Weeds	0200 Water	0212 Biolgoy-Env	105	5206-20280-001	21,000	0.2	12,000	0.15
4700 Weeds	0200 Water	1310 Physiology	105	5206-20280-001	10,000	0.1	9,000	0.1
4700 Weeds	0200 Water	1312 Physiology	105	5206-20280-001	18,300	0.2	10,000	0.1

APPENDIX TABLE 1 Continued

Activity	Commodity	Science	RPA	Work Unit	ARS Funding	SY	Other Funding	SY
4700 Weeds	0200 Water	1524 Chem-Anal	105	5206-20280-001	$ 8,500	0.1	10,000	0.1
4700 Weeds	0200 Water	1526 Chem-Organic	105	5206-20280-001	10,000	0.1	10,000	0.1
4700 Weeds	0200 Water	0212 Biology-Env	105	7615-20280-004	18,242	0.2	19,294	0.2
4700 Weeds	0200 Water	0912 Nutrition	105	7615-20280-004	4,560	0.05	4,824	0.05
4700 Weeds	0200 Water	1312 Physiology	105	7615-20280-004	18,242	0.2	19,294	0.2
4700 Weeds	0200 Water	1524 Chem-Anal	105	7615-20280-004	4,560	0.05	4,824	0.05
4700 Weeds	0200 Water	0412 Entomology	105	7602-20280-002			5,500	0.05
4830 Pollutant	0200 Water	1524 Chem-Anal	901	5604-20280-003				
4830 Pollutant	3950 Irrigate	1525 Chem-Anal	701	5604-20280-003				
4830 Pollutant	0200 Water	0212 Biology-Env	901	5206-20281-001	10,500 1/	0.2		
4900 Bio-Pl	6100 Weeds	1312 Physiology	318	5806-20280-001	11,450	0.2		
4900 Bio-Pl	6100 Weeds	0112 Biochem	318	5806-20280-004	9,000	0.2		
4900 Bio-Pl	6100 Weeds	0212 Biology-Env	318	5806-20280-004				
4900 Bio-Pl	6100 Weeds	1312 Physiology	318	5806-20280-004	13,250	0.3		
4900 Bio-Pl	6100 Weeds	0212 Biology-Env	318	5206-20280-001	8,000	0.1	25,000	0.25

1/ Pilot Test funds.

Appendix Table 2

Activity Profile for Program 677 - Plant Production Efficiency
Scienties Years by Commodities as Of December 1976

Commodity	4500 Insct	4600 Dis&n	4700 Weeds	4830 Polln	4840 Climx	Other Protc	4900 Biol	5000 Effic	5100 Accpt	5200 Mechz	5300 Systm	Other	Total
0100 Soil and Land	.0	.0	.0	.5	.0	.0	.0	.0	.0	.0	.0	3.0	3.5
0200 Water	.0	.0	8.9	.3	.0	.0	.0	.0	.0	.0	.0	.4	9.6
0600 Trees Forests &	2.8	2.6	.0	.5	.7	.0	.0	.1	4.4	.9	.0	.4	12.4
0700 Range	3.4	.8	11.4	.0	.3	.0	2.2	7.3	.0	.0	.0	13.3	38.7
0900 Citrus & Subtro	17.2	9.0	.0	.0	.0	.0	.0	10.6	1.2	5.4	.0	.0	43.4
1000 Decidus & Sma F	16.4	11.9	.9	.9	.2	.0	.3	23.0	1.3	6.1	.0	2.4	63.4
1100 Potatoes	3.7	7.9	.2	.0	.0	.0	1.0	3.1	2.0	.1	.0	.0	18.0
1200 Vegetables	19.9	22.5	3.0	.0	.0	.0	1.8	9.9	4.2	3.6	.0	.0	64.9
1300 Ornamentals & T	4.1	4.7	.9	.6	1.2	.0	5.5	6.6	4.1	.0	.0	.3	28.0
1400 Corn	31.0	17.3	2.2	.0	.1	.0	5.2	8.5	2.0	.0	.0	.0	66.3
1500 Grain Sorghum	2.5	2.2	.4	.0	.0	.0	1.2	8.2	.0	.0	.0	.0	14.5
1600 Rice	1.3	1.5	1.0	.0	.0	.0	.0	3.2	1.3	.0	.0	.0	8.3
1700 Wheat	7.9	23.9	.8	.0	.2	.0	1.1	6.6	11.9	.0	.0	.0	52.4
1800 Other small Gra	4.4	15.4	.2	.1	.8	.0	1.2	11.4	5.9	.0	.0	.1	39.5
1900 Pasture	.3	.0	3.8	.0	.0	.0	.2	1.6	.0	.6	.0	.0	6.5
2000 Forage Crops	10.7	11.2	3.5	.2	1.6	.0	4.4	36.7	1.6	3.2	1.3	.0	74.4
2100 Cotton	62.2	18.2	5.2	.0	.0	.1	2.1	25.9	8.7	9.4	.0	.2	132.0
2200 Cottonseed	.0	.0	.0	.0	.0	.0	.1	.0	1.0	.7	.0	.0	1.8
2300 Soybeans	7.8	17.8	6.4	1.2	.0	.0	6.0	13.9	2.4	2.2	.0	.0	57.7
2400 Peanuts	1.1	2.7	.8	.0	.0	.0	.0	2.1	1.2	2.1	.0	.0	10,0
2500 Other oilseed A	.9	3.6	.4	.0	.4	.0	1.0	5.1	.5	.0	.0	.0	11.9
2600 Tobacco	5.0	5.0	.0	.8	.0	1.4	.0	6.1	5.9	3.2	.0	1.1	28.5
2700 Sugar Crops	6.5	20.9	2.4	.0	.3	.7	1.2	13.2	3.8	1.0	.0	.7	50.7
2800 Miscellaneous A	3.0	1.7	.2	.0	.0	8.2	.6	5.4	.9	.5	.0	5.4	25.9
2900 Poultry	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2
3000 Beef Cattle	1.0	.0	.0	.0	.0	.0	.0	1.4	.0	.0	.3	.0	2.7
3100 Dairy Cattle	1.4	.0	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	1.7
3300 Sheep and Wool	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3
3500 Bees and Honey	1.6	.8	.0	1.2	.6	.0	2.9	14.3	.0	2.0	.0	2.1	25.5
3900 Housing Equipme	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.6	.0	.0	2.6

Appendix Table 2 Continued

Commodity	4500 Insct	4600 Dis&N	4700 Weeds	4830 Polln	4840 Climx	Other Protc	4900 Biol	5000 Effic	5100 Accpt	5200 Mechz	5300 Systm	Other	Total
4000 People as Workers	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1
6100 Weeds	.0	.0	.0	.0	.0	.0	12.0	.0	.0	.0	.0	.0	12.0
6200 Seed Research	.0	.0	.0	.0	.0	.0	1.5	3.1	.0	.0	.0	.0	4.6
6300 Biological Cell	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.1
6500 Invertebrates	6.7	.0	.0	.0	.0	.0	93.0	.0	.0	.0	.0	.0	99.7
6600 Microorganisms	.0	.0	.0	.0	.0	.0	7.5	.0	.0	.0	.0	.0	7.5
6700 Plants	7.3	2.4	2.3	14.1	.0	.0	36.5	3.0	.0	.0	.0	1.1	66.7
6800 Animals Vertebr	1.8	.0	.0	.5	.0	.0	.0	.0	.0	.0	.0	.0	3.1
7000 Res Equip & Tec	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	3.8	3.8
	232.5	204.0	54.9	20.9	6.4	11.2	188.6	230.6	64.3	43.6	1.6	34.3	1092.9

Summary of SEA Research on Control of Aquatic Weeds

Scientists and Locations:

Davis, California	
P. A. Frank	Plant Physiologist
R. R. Yeo	Botanist
Denver, Colorado	
L. W. J. Anderson	Plant Physiologist
Ft. Lauderdale, Florida	
K. K. Steward	Plant Physiologist
T. D. Center	Entomologist
Gainesville, Florida	
G. Buckingham	Entomologist
Prosser, Washington	
R. D. Comes	Plant Physiologist
L. Y. Marquis	Plant Physiologist
Stoneville, Mississippi	
P. C. Quimby	Plant Physiologist
WRRC-Albany, California	
K. L. Stevens	Chemist

All of the research conducted by SEA on control of aquatic weeds is carried on by the individuals listed above. These scientists represent 9 SY of research effort in various aspects of control, physiology, ecology, biochemistry, and herbicide evaluation and registration. The breadth of research, and the number of individual problem weeds and aquatic sites dealt with, make it impossible for so few scientists to make concerted and in depth approaches to the solution of problems. Research in progress by location and by individual scientist as of October 1976 is presented below. The listing is comprised of project titles and objectives.

Davis, California

Title - Control of weeds and certain other aquatic pests in the Pacific Southwest.

Objectives - Investigate individual and integrated approached to control of aquatic weeds by use of herbicides, biological control agents, and ecological modification of the aquatic habitat. In-

vestigated physiology, ecology, and biochemistry of aquatic plants in order to understand why weed problems occur, and how effective control programs can be devised.

Work Unit 5206-20280-001
P. A. Frank and R. R. Yeo 1.5 SY

Title - Biological control of aquatic weeds with plant competitors.

Objectives - Determine the efficacy of spikerush as a biological control for aquatic weeds and develop procedures for its use as an established field practice.

Work Unit 5206-20281-001
P. A. Frank and R. R. Yeo 0.5 SY

Denver, Colorado

Title - Uptake and movement of herbicides and nutrients in aquatic weed species.

Objectives - Determine the specific modes of uptake of existing and potential aquatic herbicides and examine the environmental conditions which may affect uptake rates. Elucidate the translocation characteristics of aquatic herbicides to assess their potential in controlling reproductive organs of aquatic weeds.

Work Unit 5604-20280-003
L. W. J. Anderson 0.4 SY

Title - Hormonal regulation of growth, development and vegetative propagation of submersed aquatic weeds.

Objectives - Determine the role of natural plant growth regulators in controlling development and germination of vegetative propagules of American pondweed (*Potamogeton nodosus*). Determine the effects of temperature and light on development in relation to growth regulator function.

Work Unit 5604-20280-004
L. W. J. Anderson 0.5 SY

Title - Identify effective, new aquatic herbicides and algicides. Determine the phytotoxicity of irrigation water containing aquatic herbicides on crops and the extent of herbicide residue retention in the exposed crops. Determine the level of herbicide residue in water resulting from the application of herbicide to irrigation canals, or impoundments.

Work Unit 5604-20280-005
L. W. J. Anderson 0.1 SY

Ft. Lauderdale, Florida

Title - Biological control of weeds in the Southeast.

Objectives - (1) To introduce the insects Neochetina eichhorniae, Neochetina bruchi, Sameodes albiguttalis, and others which may be cleared for control of waterhyacinth. (2) To evaluate the control effects of these species individually and together in different field sites. (3) To determine means of enhancing the degree of control to be obtained using fungi, chemicals, collection and distribution techniques, and combinations with other animals which attack the weed. (4) To assess other arthropods against other species.

Work Unit 7615-20280-005
T. D. Center 1 SY

Title - Physiology and control of aquatic weeds.

Objectives - (1) To develop basic information on nutritional requirements of aquatic plants including the means of uptake and translocation of mineral nutrients and organic substances. (2) To determine ecological requirements of problem species in regard to light, temperature, soil substrate, water quality and other parameters; determine which of these parameters may be manipulated to produce habitats unfavorable to undesirable vegetation or to encourage development of desirable species. (3) To identify weak links in the life cycles of problem weed that may make individual species amenable to management. (4) To evaluate chemicals in the laboratory and field for efficacy in selective removal or growth regulation of problem weed species. (5) To develop more efficient methods of measuring phytotoxic or growth modifying responses of aquatic plants to chemicals to decrease the time and cost required for evaluation. (6) To improve technology of chemical aquatic weed control in flowing water by investigating relationships between concentration and contact time of chemicals, of absorption, translocation and accumulation of chemicals and how these factors affect plant growth.

Work Unit - 7615-20280-004
K. K. Steward 1 SY

Gainesville, Florida

Title - Identification of insects for biological control of aquatic weeds.

Objectives - (1) To clear South American insects for the control of waterhyacinth. (2) Test European insect Parapoynx stratiotata for possible use in controlling Eurasian watermilfoil. (3) Investigate biological control potential for the submersed aquatic weed hydrilla.

Work Unit 7602-20280-002
G. Buckingham 1 SY

Prosser, Washington

Title - Control of weeds in aquatic and noncrop areas in the Pacific Northwest.

Objectives - (1) Study the seedling vigor, adaptability, growth habit, competitive ability, and herbicidal tolerance of selected perennial grass species and plant introductions for suitability as replacement vegetation on weedy ditchbanks.

Work Unit 5806-20280-001
R. D. Comes 1 SY

Title - Control of weeds in aquatic and noncrop areas in the Pacific Northwest.

Objectives - (1) Study the absorption, translocation, and metabolism of herbicides and plant growth regulators in submersed, emersed and ditchbank plants. (2) Evaluate the relative importance of roots and foliage in the uptake of nutrients in the aquatic environment required for growth and development. (3) Investigate possible allelopathic interactions between aquatic species.

Work Unit 5806-20280-004
L. Y. Marquis 1 SY

Stoneville, Mississippi

Title - Life history and physiological studies of aquatic and marginal weeds.

Objectives - (1) Conduct life history studies on aquatic weeds in order to improve weed control through a better understanding of their physiological, biochemical, and ecological characteristics. (2) Develop biological and ecological methods of control in order to reduce dependence on herbicides.

Work Unit 7402-20280-001
P. C. Quimby 1 SY

WRRC-Albany, California

Title - Phytotoxins from aquatic plants, bacteria, and fungi.

Objectives - To isolate, identify, and synthesize natural phytotoxins from aquatic plants, bacteria, and fungi, and evaluate their potential as aquatic herbicides.

Work Unit 5102-20280-001
K. L. Stevens 1 SY

Recent Major Accomplishments by SEA Scientists in Aquatic Weed Control Research

1. Discovered several new herbicides that have potential for control of aquatic weeds.

   There are few registered aquatic weed herbicides. Almost all of these have characteristics that limit their use or make their use hazardous. Among the promising new herbicides are Velpar, terbutryn, buthidazole, and several confidential compounds.

2. Developed improved techniques for herbicide applications.

   The use of appropriate herbicides in specific sites has led to retardations of growth of *Hydrilla* for as long as 13 months with the herbicide fenac, and for as long as 36 months with dichlobenil. The use of invert emulsions has led to higher levels of herbicides in *Hydrilla* and to a more rapid, uniform, and complete phytotoxic response of the weeds.

3. Discovered selections of redtop and creeping red fescue grasses that are tolerant of herbicides used for control of ditchbank weeds.

   The use of these grasses, selected from numerous domestic and introduced varieties, makes is possible to establish cover for ditchbanks. Subsequent use of herbicides, such as glyphosate, permits removal of large troublesome species like reed canarygrass without the danger of denuding the banks. Once established, the grasses aid in preventing reinfestation by both grass and broad-leaved weeds.

4. Developed data on dissipation of glyphosate, dalapon, MSMA, and simazine in irrigation water and residues in crops irrigated with water containing these herbicides.

   SEA is the only agency in the U. S. that develops data of this nature. The findings in this research are critically needed for registration of the herbicides for use in weed management programs on irrigation canals and ditches.

5. Determined host specificity of introduced species of insects released for control of alligatorweed and waterhyacinth, and investigated the ecological parameters of importance to the weeds and their insect predators.

Data from the host specificity studies are absolutely essential to assure that the introduced and released species do not constitute a hazard in their new environment. A knowledge of the ecological requirements of both the host plants and the biocontrol agents is needed for successful release and establishment of control agents.

6. Instituted a biological control program for waterhyacinth with introduced species of insects. Evaluated an insect for control of *Hydrilla*.

   The introduced insects, *Neochetina eichhorniae* and *N. bruchi* were established on waterhyacinth. The former is now present in approximately 200 sites. Generally, in the older sites, the size and density were reduced by *N. eichhorniae* by about 50%. By combining *N. eichhorniae* with one or more of the following biocontrol agents, *Acremonium zonatum*, *Orthogalumna terebrantis*, and *Ctenopharyngodon idella*, synergistic actions could be observed. A chemical attractant or feeding stimulus was discovered in waterhyacinth. When stems of the plants were broken, *N. eichhorniae* populations increased 8 to 16 fold, making collection and new releases easier. A moth (*Parapoynx diminutalis*) that feeds on *Hydrilla verticillata* was discovered at Fort Lauderdale, Florida. While not specific for control of *Hydrilla*, it is attracted strongly to this species. Rearing capability for this insect was developed to produce 10,000 eggs per day.

7. Developed procedures for the use of plant competitors as a biological control for vascular aquatic weeds.

   It was discovered that the small species of spikerush (*Eleocharis*) could be planted or otherwise encouraged to invade stands of large and troublesome species of aquatic weeds. Once established, the spikerush forms a dense sod that can eliminate other plants and prevents their reestablishment. This development provides an additional control measure that is especially useful in instances where other forms of control may not be used. The spikerush poses no hazard to the environment and, once established, it is self perpetuating.

8. Demonstrated an allelopathic relationship between spikerush and other vascular aquatic plants.

   It was shown experimentally that spikerush produces a phytotoxic compound(s) that limits the growth and affects

reproduction of aquatic plant species such as the pondweeds. This is a new and promising concept in aquatic weed control, and one that should be developed to the fullest extent. Allelopathy is probably more common in natural systems than is realized, and recognition and utilization of those allelopathic relationship that exist are essential in devising effective biological and integrated control procedures.

9. Established a physiological and biochemical basis for the development and germination of sago pondweed tubers and American pondweed winterbuds.

   These investigations demonstrated that rhizome production in American pondweed is influenced by light. The removal of rhizomes or daughter plants disturbed the normal sink-source relationship in the parent plant. Exogenously applied ethylene stimulated sprouting and growth of the tubers and winterbuds, while exogenously applied abscisic acid inhibited germination. Low concentrations of abscisic acid caused American pondweed winterbuds to produce only floating leaves and stunted plants. These effects could be reversed by gibberellic acid, benzyladinine, or zeatin. These findings suggest that tuber dormancy may be controlled by balances of endogenous abscisic acid-like and gibberellic acid-like regulators, and that leaf morphology may be determined by abscisic acid. This research is important because many of the most troublesome aquatic weed problems develop from the overwintering vegetative propagules. A thorough understanding of the physiology of their production and growth may provide a means by which they can be eliminated and the weed growths controlled.

10. Discovered that the growth of floating and partially emersed aquatic weeds is inhibited by low oxygen levels and by submergence in darkness, Growth of the same weeds can be promoted or reestablished by red light, hydrogen peroxide, or exposure to air.

    This information explains why herbicides that inhibit photosynthesis are more effective on submersed weeds than on partially submersed weeds. Is also provides some direction in the search for new herbicides that are effective in control of aquatic weeds.

SUBCOMMITTEE REPORT ON RESEARCH NEEDS AND RESPONSIBILITIES 1/

The subcommittee expressed its concern over the increasing seriousness of aquatic weed problems, the cost of weed control, and the losses to agriculture and other industries that rely on an adequate supply of water of good quality. Several examples of serious problems cited were: (1) the recently discovered infestation of hydrilla in the All American Canal and several hundred miles of irrigation water distribution systems of the Imperial Irrigation District in California, (2) Eurasian watermilfoil infestations in Bureau of Reclamation and Corps of Engineer reservoirs, and (3) infestations of aquatic weeds in the O'Neill Forebay of San Luis Reservoir (a joint facility of the Bureau of Reclamation and the California Department of Water Resources).

The subcommittee concluded that present levels of support in funds and personnel were seriously inadequate to provide the new aquatic weed control technology required to meet current and future needs of government agencies and the public. There are approximately 50 floating and submersed aquatic weeds in the United States that cause serious problems, and most of these are widely distributed. There are numerous others that are creating problems locally or becoming problems under certain conditions. There is about the same number of marginal and ditchbank weeds that also cause severe problems. Most of these weeds may be present in a wide variety of aquatic sites and habitats. Solutions to most aquatic weed problems are influenced strongly by (1) the species of weeds, (2) the nature of the plant growth (submersed, floating, or other) and the site, (3) the use or uses made of the water (irrigation, municipal, recreation, or other), (4) the presence of fish or other desirable forms of aquatic animals, (5) the presence of desirable aquatic and ditchbank vegetation, (6) the toxicity of herbicides to irrigated crops, (7) the problems of chemical residues in irrigated crops, fish, and in water consumed by man or livestock, (8) the absence of known biological control agents, (9) the scarcity of knowledge with regard to the physiology, ecology, biochemistry, and various other life processes of aquatic plants, (10) the absence of residue tolerances and registration for use of specific herbicides, (11) the limited number of aquatic herbicides available, and (12) the high cost of all control methods now employed. SEA presently devotes 9.5 SY to all aspects of research on aquatic plants. When considered in light of the extensive need for fundamental research on the physiology, ecology, and biochemistry of aquatic plants; for discovery and development of biological control agents; for more effective and economical methods for mechanical control, harvesting and utilization of aquatic weeds; and integrating the control techniques developed; it is evident that the level of research effort must be increased in order to provide solutions to the complex weed problems faced by water managers.

Research Approaches, Goals, and Missions. Subcommittee members were advised that there was need for new and more comprehensive approaches

1/ Recommendations in these reports are not necessarily listed in order of priority.

to research on aquatic weed control. Because of the immediacy of problems and the need for quick solutions, research personnel often find it necessary to stress lines of research that offer the greatest potential for developing a usable technology in the shortest possible time. More basic research must often be delayed. The subcommittee concluded that some improvement was needed in establishing research priorities. This would be more readily accomplished when the base of research could be broadened by additional research personnel, a greater varity of scientific disciplines, and coordinated effort among state and Federal Agencies. It was agreed that more research should be devoted to: (1) development of biological control methods for a greater number of weeds; (2) discovery, evaluation, and development of new, more effective and acceptable herbicides; (3) development of data on efficacy, residues, environmental effects, and safety that are required for registration and tolerances for aquatic herbicides.

Regarding the mission of SEA in relation to aquatic weed control, the subcommittee agreed that it was described appropriately in SEA-WRP 20280 "Weed Control Technology for Protecting Crops, Grazing Lands, Aquatic Sites, and Noncropland." This document states that: "Important Missions of the Science and Education Administration, Federal Research are to: (a) develop the technology needed to assure an adequate supply of high quality food, feed, and fiber; and (b) improve the quality of the environment for man and animals. Weed control technology is essential to achieving this mission". SEA-NRP 20280 also states that the SEA research program is conducted in cooperation with other Federal Agencies, State Agricultural Experiment Stations, private universities and research institutions, and industrial research organizations. SEA research supports regulatory and operational programs of the several Federal Agencies concerned with water and land resources use and management.

Subcommittee members agreed that SEA has the statutory authority to respond to the needs for aquatic-site and weed control technology of federal, state, and local government agencies and the public. It was emphasized, however, that other state and federal agencies responsible for the management, operation, and maintenance of water resource systems also have important responsibilities for development of aquatic-site weed control technology.

Strategy for Obtaining Required Research Resources. In view of budget difficulties encountered by the individual federal agencies, it was concluded that a more effective approach to requests for research resources is required to obtain the personnel, funding, and facilities necessary to meet current and future research needs. Such an approach can be enhanced by: (1) development of appropriate Memorandums of Understanding among the several agencies that have research management responsibilities for water resources, (2) appropriate assignment of research missions and responsibilities, and (3) strong and coordinated interagency support of budget proposals for an expanded research program.

Memorandums of Understanding. The nature and function of Memorandums of Understanding (MOU) were discussed by the subcommittee. An example was given of a cooperative research program between SEA and the Bureau of Reclamation (now including the Fish and Wildlife Service) that has been in existence for more than 25 years. During this period the pro-

gram was carried on under provisions of a MOU that spelled out the obje tives of the program and the roles and responsibilities of each agency. In order to derive the maximum benefit from MOU's, they should involve a greater number of agencies, and they should provide the base from which the cooperating agencies may coordinate both the research activities and proposals for funding and personnel increases for research on aquatic weed control.

Division of Responsibility. In order to avoid unnecessary duplication of effort and to ensure the most productive allocation and use of resources, there must be approariate division of tasks and responsibilities among Federal Agencies and other organizations who have need for aquatic weed control technology. The Subcommittee on Research Needs and Responsibilities concluded that a "lead agency" concept should be developed and adhered to by the agencies and organizations concerned with research and water management. Under this concept, the agencies and organizations would undertake those tasks that are compatible with their missions, personnel, and facilities.

It was concluded that SEA should be primarily concerned with basic and developmental research on the various approaches to aquatic weed control. Water management and other user agencies and organizations employing research data developed by SEA scientists, would collaborate in the applied aspects of the research, participate in advanced field testing and pilot applications to establish general use patterns, corroborate existing data on environmental hazards, develop additional supporting data for registration and establishment of tolerances, and undertake actual control and eradication activities. The division of responsibilities should be developed through mutually agreeable arrangements set forth in the MOU's.

Coordination of Personnel and Funding Requests. At the present there is some coordination of technical programs among Federal Agencies, but little or no coordination of requests for financial support and manpower for aquatic weed control research. The subcommittee concluded that steps should be taken to insure that bureau and agency administrators are informed of the importance of aquatic weeds and the need for research on their control. In particular, agencies with research and water management responsibility should provide coordinated and unified support of requests to departmental budget officers and the Office of Budget and Management for funds and personnel for aquatic weed control research and for the adaptive and applied research needs of water and land management agencies.

Initiatives Taken or in Progress. It was reported during the subcommittee discussions that a number of steps have been taken or are in progress to strengthen interagency and interdepartmental cooperation and coordination. These include:

1. Reactivation of the Weed control Committees of the Departments of Agriculture and Interior.

2. Organization of a Federal Aquatic Plant Management Working Group.

3. Revision and strengthening of the existing MOU between SEA, Fish and Wildlife Service, and the Bureau of Reclamation.

4. Discussions by SEA and Corps of Engineers representatives regarding a MOU to guide joint aquatic weed control programs.

5. The Federal Aquatic Plant Management Working Group has planned to undertake a survey of aquatic weed problems in the United States in order to provide accurate and comprehensive information regarding the magnitude of the problems and the losses incurred.

6. The Weed Control Committees of USDA and USDI have established four work groups; (a) Work Group on Biological Control of Weeds, (b) Work Group on Registration Requirements for Aquatic Herbicides, (c) Work Group on Improving the Preventive Weed Control Provisions of the Federal Seed Act, and (d) Work Group on Integrated Weed Management Systems.

The subcommittee agreed that continued effort should be devoted to broadening the base of support and cooperation by developing working agreements with additional agencies such as APHIS, SCS, and EPA. In time a mechanism should be developed for acquiring participation and involvement of state, local, and private water resource management groups.

Research Locations and Staffing. SEA/FR now has aquatic weed research programs located at Davis, California; Denver, Colorado; Fort Lauderdale, Florida; Gainesville, Florida: Prosser, Washington; and Stoneville, Mississippi. All of these programs are manned by 1 or 2 SY. This distribution does not provide for research on aquatic weed problems in the northeast, midwest, or southwest. However, the subcommittee concluded that it would be more desirable to strengthen existing research programs before considering new research locations.

The subcommittee was in agreement that future staffing should result in a broader disciplinary mix of scientists at a given location. The disciplines would be determined by the principal goals and objectives of research at the location.

Aquatic weed problems of the contiguous 48 states can be separated broadly into those of the arid west and those of the humid eastern and southeastern regions. Consequently, the subcommittee proposed that priority by given initially to expansion at two locations to provide facilities and staff required for a broadly based interdisciplinary research approach. Fort Lauderdale, Florida was suggested as a logical site for an expanded research program in the eastern United States, and Davis, California for an expanded research program in the Western United States.

Data for Herbicide Registration. The number of herbicide chemicals now registered by EPA is very small. Restrictions on the use of registered

aquatic herbicides are numerous and prevent their use in many aquatic sites. Many of the restrictions are due to lack of data concerning residues and possible environmental hazards. The subcommittee concluded that SEA/FR should be more extensively involved in developing such data so as to permit wider use of existing aquatic herbicides, and hasten the registration and use of new herbicides. It was pointed out that the Interregional Research Program (IR-4) has not concerned itself in the past with registration of aquatic herbicides. The subcommittee agreed that increased effort should be made to secure the assistance of this group in obtaining the registrations required.

Soft-funded Research and Personnel Ceilings. A significant part of research performed by SEA/FR on aquatic weeds is supported by state and federal user agencies. Strict personnel ceilings reduce the SEA capability to staff adequately and effectively. The highest priority for the limited number of SEA personnel must be assigned to programs directed by the USDA and Congress. As the number of personnel available to SEA/FR is diminished, research units find it more difficult to cooperate with the user agencies in performing research of mutual interest. The subcommittee members agreed that the Department of Agriculture and the other Federal Agencies interested in research on aquatic weed control should explore with the Office of Management and Budget the provision of additional temporary and permanent positions for SEA scientists engaged in aquatic weed control research to permit SEA to conduct needed research with funds provided by the user agencies and organizations.

Aquatic Weed Problems and Loss Assesment. There was general agreement that one of the most serious needs was current, comprehensive, and accurate data on the extent of aquatic weed problems and the losses caused by the weeds. Strong support was given to the suggestion that some means be developed for surveying the weed problems, assessing financial losses, and determining the environmental and social impacts. It was suggested that the Federal Aquatic Plant Management Working Group, now planning such a survey, secure the assistance of the Economic Research Service and other agencies capable of providing assistance.

Training of Weed Scientists. The subcommittee agreed that SEA and cooperating agencies should encourage the training of future weed scientists to the extent possible through support of research by state universities, agricultural experiment stations, and private institutions.

Subcommittee Members

P. A. Frank, SEA, Chairman
T. H. Seldon, USBR, Vice Chairman
D. E. Bayer, U. of California
B. L. Berger, USF & WS
S. N. Brooks, SEA
D. F. Davis, SEA
J. L. Decell, Corps of Engineers
R. T. Durbrow, WAA of CA
E. E. Haskell, SEA
E. B. Knipling, SEA
C. W. Nichols, CDWR
R. L. Olson, SEA

D. Owen, CDWR
R. C. Roberson, CDWR
P. van Schaik, SEA
W. C. Shaw, SEA
J. M. Vetterling, SEA

SUBCOMMITTEE REPORT ON BIOLOGICAL CONTROL

Biological control is recognized and accepted as an important segment of pest management systems. As the need for pest management increases, the desire for biological control as an alternate method of control becomes more evident. Although there are numerous examples of biological control, its potential for control of pests of man has scarcely been touched.

Aquatic plants make up a very diverse group of species. Many species exist totally submersed, others are largely floating, and still other species are partially submersed and partially emersed and exposed to the atmosphere. Because of the differences in habitat, the range of effective biocontrol agents must be very broad. The total number of certain parasitic organisms, such as insects, capable of existing on submersed weeds is limited when compared with terrestrial or nonsubmersed aquatic species. Consequently, it is not surprising that the most successful biological agents developed to date for control of aquatic weeds are insect parasites of floating or emersed species.

Numerous biological control agents have been studied and tested on aquatic weeds during the past 20 years. A few were found to be effective and are currently in use.

Recent Major Accomplishments

1. White amur or grass carp. This introduced fish is recognized widely for its ability to control almost all species of vascular aquatic weeds and filamentous algae. It is employed for aquatic weed control in many countries. In the U.S. , Arkansas is the only state making extensive use of the fish in public waters. Most states prevent introduction of the white amur because of lack of conclusive evidence that it will not itself become a pest.

2. *Agasicles* beetle and the *Vogtia* moth. These two insects were introduced into the U.S. from South America and are presently providing substantial control of alligatorweed (*Alternanthera philoxeroides*).

3. *Neochetina eichhorniae* and *N. bruchi*. These two weevils were introduced from Argentina and provide partial control of waterhyacinth (*Eichhornia crassipes*).

4. *Cercospora rodmani* and *Acremonium zonatum*. These are two indigenous pathogens that appear to provide partial control of waterhyacinth.

5. Competitive plants. Species of spikerush (*Eleocharis* spp.) were shown to be able to eliminate stands of larger and troublesome species of vascular aquatic weeds.

Other less widely tested or accepted biological control agents are *Tilapia*, common carp, and waterfowl. Introduced plant pathogens are presently being studied at a quarantine laboratory at the University of Florida.

Despite the very modest effort devoted to research on biological control, there are a number of very significant achievements. The accomplishments suggest that further research is needed to inventory both exotic and indigenous natural enemies. Emphasis should be placed on a search for enemies of the major introduced aquatic weeds. These are least likely to be accompanied by their natural enemies and opportunities for success are better.

Present Level of Research on Biological Control

SEA presently has about 3.6 SY devoted to biological control of aquatic weeds. The distribution of this effort is 1 SY at Ft. Lauderdale, 1 SY at Gainesville, 1 SY at Davis, 0.2 SY at WRRC, and 0.4 SY at Prosser. The approximate number of non-SEA SY is 8. Three SY are expended by the University of Florida on the study of pathogens, about 3 SY are studying the use of the white amur fish for the Florida Departments of Natural Resources and Fish and Game, the University of California expends 1 SY on the study of *Tilapia* fish for weed control, and several scientists at other locations spend fractions of an SY on various other aspects of biological control.

The above appears to be a significant effort on biological control research. However, the bulk of the research is concentrated in two areas (pathogens on two weeds, and the practical application of *Tilapia* and white amur). While this research is of great importance, there is a large number of weeds and vast areas where results of the research are not applicable. The need for research on biological control for these instances and areas is critical.

Recommendations

1. Survey and identify foreign natural enemies of potential value for biological control of aquatic weeds. Emphasis should be on *Hydrilla*, Eurasian watermilfoil, and waterhyacinth. Recommended 3 SY, 1 pathologist and 2 entomologists. Each SY would have competence in both disciplines. Because of problems involved in foreign research by SEA scientists, the initial program might be conducted by research grants. A list of priority weeds, handling guidelines, and a timetable of progress and events should be developed. Supplemental studies in quarantine facilities in the U.S. are required to develop improved techniques for host specificity work.

Concurrent surveys are needed to identify natural indigenous enemies of introduced and nonintroduced aquatic weeds. For this research it is recommended that 5 additional SY be assigned and located as follows: 1 microbiologist at Davis and 1 plant pathologist at Ft. Lauderdale to search for and study plant pathogens as biological control agents; 3 entomologists located at Ft. Lauderdale to study basic insect-plant relationships, and to release promising insects as control agents, carry out insect and host manipulation studies, and evaluate results.

2. Intensify research on modes of action of natural enemies in controlling aquatic weeds, the environmental and habitat requirements of natural enemies, and the impact of control agents on the aquatic environment. It is recommended that SEA devote an additional 3.5 SY to this research. The locations

and disciplines recommended are 1 plant physiologist at Davis, 1 plant pathologist at Ft. Lauderdale, and 1.5 chemists at the Western Regional Research Center.

3. Develop improved methods for implementation and utilization of natural enemies of aquatic weeds by practices such as; periodic inumdative releases, control of parasites of the natural enemies, and inducing attacks by natural enemies by modifying the mechanisms of natural resistance of the host plants. No additional SY are recommended for this research. These studies can be carried out by personnel assigned in item 2 above.

4. It is recommended that plant breeding research be initiated to select and develop desirable species to replace those currently causing problems in aquatic and ditchbank sites. It is recommended that 1 SY (plant geneticist) be located at Prosser.

The subcommittee deliberated at length on the potential and problems involved in the use of the white amur for control of aquatic weeds. There is little question concerning the ability of the fish to control algae and vascular weeds. There is, however, a very strong bias against the fish because of possible detrimental effects on native fisheries and the overall effect on the habitat of other aquatic life. While much research has been done on use of the white amur, very little of it has been directed toward solving the critical problems that presently restrict its extensive use.

The subcommittee agreed that a multidisciplinary team be formed to include a limnologist, fish biologist, aquatic ecologist, weed control specialist, and possibly others. The group should include one SEA scientist, to be located at some site such as Auburn, Alabama. Research on the white amur should include investigations in expansive open water areas in one of the states where it is now present, and should also be tested in confined areas such as ponds and other closed and manageable systems. Some aspects of the research, such as natural reproduction and long-term effects in large open water systems may take as long as 20 years to complete. Results of research on the fish in other countries should also be followed closely.

The subcommittee agreed that there was very limited potential for use of any of the indigenous fishes and low priority should be given to such research. Other aquatic animals in North America were likewise considered of little value for weed control, and while research on these agents may continue, it should not be encouraged and should be given only low priority.

Subcommittee members

L. A. Andres, Chairman, SEA
T. E. Freeman, Univ of Florida
W. V. Johnson, CDWR
G. W. McCammon, CA F & G
B. D. Perkins, SEA
K. L. Stevens, SEA
R. R. Yeo, SEA

Subcommittee Report on Fundamental Research In Aquatic Weed Control

I. Introduction

Weed Research, in general, includes a wide range of investigative activities which may or may not be directed toward improving specific weed control practices. Such research activities can involve herbicide delivery systems, chemical screening, host-pathogen relationships, weed ecology, and weed biology. However, we have defined Fundamental Research as those investigations that explain the mechanisms responsible for observed biological phenomena.

We have further confined our focus to the plant itself. Fundamental knowledge of aquatic plant biology is essential to achieve any significant improvement in aquatic weed control, regardless of the control strategy to be developed. Likewise, by developing new knowledge on the fundamental processes of aquatic weeds, we should be able to improve weed control regardless of the nature or geographical location of the weed problem.

II. Status of Fundamental Research on Aquatic Weeds.

A. SEA research and accomplishments

1. Currently, fundamental research is conducted, to varying degrees, at five locations: Davis, CA, Denver, CO. Ft. Lauderdale, FL, Prosser, WA, and Stoneville, MS. It is estimated that total fundamental research effort is less than two SY, since the majority of the SY in aquatic weed control are diverted to non-fundamental research.

2. Over the past 15 to 20 years, most fundamental research accomplishments have involved herbicide uptake and translocation phenomena and to a lesser degree factors influencing growth, development and dormancy of aquatic weeds. Specifically, the ability of pondweeds to absorb and translocate fenac and dichlobenil have been demonstrated. The importance of root and shoot uptake has been studied, but only in one or two species and only for a very few compounds. No broad understanding of the relationship between root-and shoot-mediated uptake and general plant nutrition has been obtained. Limited information on the importance of temperature, light, oxygen, and some known growth regulators on the dormancy, germination and growth of vegetative propagules has been obtained. No understanding of the physiological mechanisms controlling these processes has been garnered.

B. Non-SEA Fundamental Research on Aquatic Weeds.

In addition to efforts in the areas mentioned above, a continued, though very low level of fundamental research has been conducted by other U. S. governmental and state agencies and academic institutions. The major accomplishments are:

(a) Comparisons of plant constituents (primarlity inorganic nutrients) to external nutrient concentrations in a few species.
(b) Comparison of root and shoot uptake in one or two species for one or two elements.
(c) Comparison of carbon-fixation pathways in two or three species suggesting that photorespiration may limit productivity in some species.
(d) Limited information on the influence of temperature (general seasonality) on the production of vegetative propagules in Hydrilla and Eurasian watermilfoil.
(e) Implications of hormonal roles in germination and production of vegetative propagules of Eurasian watermilfoil.

C. Indicators of fundamental research activity in aquatic weeds. The level of research activity on aquatic weeds can be estimated by reviewing the frequency and type of publications in appropriate scientific journals. A review of papers published in the Journal of the Aquatic Plant Management Society (formerly the Hyacinth Control Journal) shows that over the past 14 years about 8.9% concerned fundamental research. (However, the trend is upward from ca. 3% the first year of publication to 10% last year). A similar review of papers in Weed Science showed that 1.3% of the papers published in the last 7 years were on fundamental research on aquatic plants and that additional 2% dealt with applied aquatic weed control. It should be noted that some of the fundamental research on plants is published in perhaps two dozen other journals, but papers on aquatic weed species probably represent less than one percent in those.

The foregoing clearly points to an extreme lack of basic biological information on aquatic weeds and, equally significant, to an abysmally low current research activity level.

III. Fundamental Research Priorities

A. Rationale for evaluating research priorities. First, as indicated in the introduction, we have emphasized research on the plant itself, rather than on a particular control strategum. Secondly, those research areas deemed most likely to result ultimately in improved control methods were given highest priority.

B. Priorities and proposed distribution of research effort. Priorities and associated manpower needs are given in the table on page 4. Note that most of the effort on the two top priority needs should be kept in-house. It is felt that the least amount of lag-time would occur by bolstering present SEA aquatic weed oriented locations. Also, for efficient functioning of research scientists, approximately two technicians would be required to support each SY.

Recent literature review reveals that centers of ongoing extramural research exist that could more efficiently and readily undertake certain specific investigations as indicated in the table.

Finally, in addition to the above recommendations, the following research areas are considered important vis à vis specific control strategies:

Biological Control:

1. host susceptibility
2. periodicity of susceptibility

Chemical Control:

1. improved, more rapid bioassay (screening) methods
2. formulation research including controlled release systems

Mechanical Control:

1. plant constituents
2. growth rates and recovery from harvesting
3. impact of harvesting on water quality

Ecology and Eutrophication:

1. succession in aquatic plant communities
2. water quality effects

IV. Relationship of Research Priorities to National Research Program 20280

The fundamental research priorities outlined here primarily contain elements of two Technological Objectives within NRP 20280:

Technological Objective 1: New and improved fundamental knowledge of the biology of weeds for development of safe, new principles and mechanisms of their control by biological, chemical, cultural, ecological, physical, and integrated methods that will avoid or minimize hazards to nontarget organisms and to other components of the environment.

Technological Objective 5: New and improved weed control technology for controlling, managing, or using weed populations to improve water quality, fish and wildlife habitats, and recreational areas in aquatic and noncropland sites.

We conclude that the research areas judged most important, and proposed for in-house SEA efforts, could be carried out through appropriately planned CRIS Units, but only if sufficient scientist and support staffing is provided. The extramural research suggested falls within one of the four mission-oriented research needs outlined in the SEA Competitive Grant Research Fund, that is, Plant Protection. It is therefore recommended that every effort be made to solicit research proposals for those specific areas best suited to extramural involvement.

Subcommittee Members

L. W. Anderson, Chairman, SEA
N. Dechoretz, SEA
R. H. Hodgson, SEA
E. B. Knipling, SEA
L. Y. Marquis, SEA
S. R. Bissell, SEA

Fundamental Research Priorities in Aquatic Weed Control

Research Priority	Distribution of Research Effort: SEA Location or other	SY	(Discipline)	Duration
I. A. Uptake, movement, exchange of nutrients and xenobiotics.				5 yrs.
*1. relative importance of root/shoot uptake	Davis, CA	1.0	(Aquatic ecology)	
	Denver, CO	1.0	(Plant Physio.-membrane)	
*2. uptake mechanisms	Stoneville, MS	1.0	(Biochemistry)	
3. passive v. active uptake	Prosser, WA	1.0	(Plant Physio.-metabolism)	
I. B. Reproductive physiology and morphogenesis.				8-10 yrs
*1. function/role of endogenous growth regulators	Denver, CO	2.0	(Plant physio.-biochem)	
*2. physiology and dormancy of perennating organs	Fargo, ND	1.0	(Natural products chem.)	
	Stoneville, MS	2.0	(Plant physio.-dormancy)	
3. photomorphogenesis and senescence			(Plant physio.-devel. physio.)	
II. Photosynthesis, respiration and metabolism.				5 yrs.
*1. carbon sources	Fargo, ND	1.0		
*2. photorespiration	Extramural	1.0		
3. gas exchange				
4. release of photosynthetic and other orangics	Extramural	1.0		
III. Nutrition.				5 yrs.
*1. minimum nutrient requirements and deficiency and toxic levels of nutrients	Extramural	1.0		
2. water chemistry and nutrient cycling	Davis or Riverside, CA	1.0	(Plant physio. soil/nutrition)	
3. significance of luxury consumption	IAG	1.0		

IV. Water relations . . . . 5 yrs.

1. evapotranspiration	IAG	1.0
2. internal water economy		
3. desiccation resistance in perennating structures	Denver, CO	1.0 (Plant physio.-devel. physio.)

*Top priorities

IAG - Interagency agreement

SUBCOMMITTEE REPORT ON CHEMICAL CONTROL OF AQUATIC WEEDS

Aquatic weeds interfere with every conceivable use of water resources. Comprehensive estimates of losses nationwide caused by these weeds have never been available and much of the fragmentary data are 10 to 15 years old. Recent estimates from isolated regions indicate that these losses have escalated drastically, in some cases there have been 10 to 15 fold increases. Updated estimates of these losses and estimates of the extent of the aquatic weed problems are urgently needed. Once in hand these estimates will provide justification for increased support to combat these problems. Updated estimates can also be used to document benefits to be gained by the public through effective control programs. Since progress in developing aquatic weed control technology has been severely retarded by lack of funding and manpower, the conduct of an in depth survey to obtain these estimates should be given a very high priority. Such a survey could be a collaborative effort between USDA agencies such as SEA/FR, Economic Research Service, the Extension Service, Statistical Reporting Service and other agencies.

Chemical control of aquatic plants is usually easier, quicker, often less expensive and more energy efficient than other available control methods. Chemicals, if properly used are safe, can give complete initial control of aquatic weeds and can eliminate or reduce propagules thus reducing some of the problems of reinfestation. Chemicals have potential for selectively removing noxious growth of aquatic plants with subsequent enhancement of more desirable growth. Chemicals can be used for habitat improvement for fisheries and water fowl by altering density and composition of aquatic vegetation.

Progress in chemical aquatic weed control technology has been retarded by lack of chemical tools, i.e., herbicides and growth regulators. The reduction in number of new chemicals and loss of older chemicals are partially due to reluctance on the part of industry to commit resources for development of chemicals for aquatic use because of vagueness of the requirements and the complexities of registration procedures.

Nonresearch

1. Conduct a nationwide survey of all aquatic weed problems and losses of all kinds that result from infestations of aquatic weeds in private and public waters.

2. All concerned agencies and groups take whatever action is necessary to encourage EPA to expedite the issuance of functional guidelines for registration of aquatic herbicides.

Research

1. Develop less costly, more effective, and environmentally safe aquatic herbicides. This can be done by improving evaluation techniques to increase the number of acceptable herbicides for use in water and on ditchbanks. The usefulness of chemical control can be expanded by devising effective

mixtures of herbicides or herbicides and growth regulating compounds, designed for specific aquatic sites and weed problems. Incorporate the use of chemicals into integrated approaches to control of aquatic weeds.

Very little research of this nature is being carried on at this time. SEA scientists devote the equivalent of 1.7 SY to evaluation and testing of new herbicides, experimental compounds, formulations, and application techniques. Total SEA effort should be increased to at least 3 SY divided among the locations at Prosser (0.5 SY), Davis (1 SY), and Ft. Lauderdale (1.5 SY).

2. Promote the registration and safe use of aquatic herbicides by determining the levels of residues and their persistence in aquatic sites and ditchbank soils following procedures recommended for weed control. Registration of aquatic herbicides can be delayed indefinitely for lack of data. These data usually involve residues and are costly and time consuming to obtain. At the present time, industry has shown no great enthusiasm for providing the data. In addition to data on levels of residues and their persistence it is essential that tolerances of crops to the residues be determined, residues and tolerances in crops be established, the fate of herbicides in water and ditchbank soils be investigated, and in some instances, means of deactivating herbicide residues in aquatic sites be developed.

Despite the limited SY devoted by SEA scientists to this effort, their contribution has been highly significant, and at times, almost the only source of this information on aquatic herbicides in the U.S. The present SY (about 0.7 primarily at Prosser and Denver) should be increased to a total of 4 SY (1 SY each at Prosser, Denver, Ft. Lauderdale, and Davis). Because of the amount of research involved in a single herbicide, only those having exceptional potential should be investigated and data developed for registration.

3. Develop more accurate and effective equipment and techniques for herbicide applications, obtaining samples of water and hydrosoil, and estimating cover and biomass of aquatic weeds. These are problems encountered by all scientists conducting research on aquatic weeds. The problems are less immediately associated with weed control and consequently no concerted research has been undertaken to improve existing equipment or techniques. SEA has no research effort directed specifically toward solving these problems. The subcommittee recommended that 2 SY be assigned to this research. One SY should be located at Ft. Lauderdale, and the other SY might involve an extramural project of 3 to 5 years duration.

4. Investigate the relationships between aquatic herbicides and the physical and chemical parameters of aquatic habitats as they relate to herbicide efficacy and toxicity to nontarget organisms. In the past, research in this area was largely ignored. The small amount of research carried out was incidental to achieving other objectives. This kind of research is very common, and considered extremely important, in control of terrestrial weeds. It is at least as important in control of aquatic weeds and much more difficult to accomplish. SEA presently devotes about 0.4 SY

at Davis to this research. The subcommittee recommended SEA expend a total of 4 SY on this research; 1 SY each at Stoneville, Ft. Lauderdale, Davis and Prosser.

The subcommittee suggested that, whenever possible, a research team approach should be utilized to satisfy present and future research needs. All of the following disciplines should be involved in some aspect of the overall research program; not necessarily at each location or each task group.

- Agricultural Engineering
- Agronomy
- Analytical Chemistry
- Biochemistry
- Entomology
- Fisheries Biology/Toxicology
- Limnology
- Microbiology
- Mycology
- Pathology
- Phycology
- Plant Ecology
- Plant Physiology
- Weed Science

Subcommittee Members

- Leon Bates, TVA
- David E. Bayer, UCD
- John Gallagher, Industry
- Robert Gates, SWFWMD
- Gary Hanson, USBR
- Robert Hummel, EPA
- Tom Jackson, USFWS
- Alice Ottoboni, CDPH
- Carlyle Tennis, USBR
- Fred Westbrook, ES
- Kerry Steward, SEA, Chairman

SUBCOMMITTEE REPORT ON ECOLOGY AND EUTROPHICATION

The subcommittee chairman, Dr. Quimby, suggested that an accurate, current assessment of aquatic weed problems was an urgent need. This project was assigned first priority as a research need in the ensuing discussion. It not only would provide the basis for estimating losses due to aquatic weeds, but would provide a baseline for future assessment to determine when problems were becoming more serious. A recent distribution study in Mississippi and an older one in California were cited. Mr. Otto mentioned that USBR will soon participate in a nation-wide survey of general aquatic weed problems, including both algae and higher plants. It was agreed that algae distributions should be studied as intensively as those of other aquatic weeds. Because of the need for a nationwide assessment, the subcommittee felt that extramural funding through state experiment stations would be most effective. An effort to map 10 states per year over a 5-year period was agreed upon. This would require about 0.2 man year and $20,000 per state. Funding could be provided by several agencies through a Memorandum of Understanding.

Second priority was assigned to research on life histories, reproduction and stress physiology, and growth kinetics of aquatic weeds. Dr. Lembi discussed her work with watermeal (<u>Wolffia</u>) and <u>Pithophora</u>. <u>Wolffia</u> reproduces by budding and forming turions, which are more resistant to chemical treatment than are floating plants. Similarly, <u>Pithophora</u> forms spores (akinetes) which tolerate higher concentrations of copper sulfate than do physiologically active cells. Thus, chemical treatments can be much more effective if they are done when the pest plant is in a vulnerable growth stage. For the same reason, Dr. Lembi recommended studies on promoting germination of spores and aquatic weed seeds. Dr. Lembi also described research on the use of a blue dye ("Aquashade") to control submerged weeds in ponds with no water exchange. The subcommittee felt that SEA research in this general area should be increased by adding 0.5 scientist years at four locations, including Ft. Lauderdale, Davis, Prosser, and one location in the northeast or north central states.

Third priority was assigned to studies on plant succession and species interactions, including competition for space and allelopathic reactions. This type of information is particularly needed for establishing desirable species after a new water body is formed and for maintaining desirable species after controls have been used on aquatic weeds. Dr. Menzel described the succession of rooted aquatic plants and planktonic algae that has occurred in ten model ponds with different levels of phosphate supplied from the hydrosoil. <u>Najas</u>, <u>Chara</u>, and <u>Potamogeton</u> species dominated in all ponds, except one with high phosphate, during the first year. Green algae came into dominance

in five ponds during the second year and in eight ponds during the third year. The succession to green algae occurred sooner at higher phosphate levels. Great variability was noted in early stages of pond development. Similar observations were reported by several subcommittee members, with the opinion expressed that the first established species may greatly influence succession of plants in ponds. The subcommittee recommended 2.5 additional scientist years in SEA effort in this area, with one each located at Ft. Lauderdale and Davis, and 0.5 at Durant.

Fourth priority was assigned to studies on engineering aspects of aquatic weed control. The topics discussed were pond and canal geometry, manipulation of water level and flow rates, and establishing dual systems of ponds or canals so that one could be used while the other was out for weed control. Mr. Miller felt that design information for pond construction was adequate for aquatic weed control. However, Mr. Otto described some problems with ditchbank weeds on irrigation canals that might be alleviated by engineering design. Reports of dual systems in foreign countries were discussed. However, the subcommittee did not agree on a needed level of effort in this area but suggested that perhaps the Bureau of Reclamation could assume responsibility for this research at Denver.

Fifth priority was assigned to sediment and water quality interactions with aquatic weeds. Dr. Lunin described work underway at the Davis Lab. where hydrosoil characteristics apparently influence establishment of spikerush (Eleocharis). He also states that organic materials and sediments in agricultural runoff seem to have important effects on aquatic weed growth. Others mentioned that not much is known of the relative importance of hydrosoil and water in the nutrition of many rooted aquatic plants. The subcommittee recommended lower priority because the prospect for weed control by nutrient limitation does not appear good. However, they agreed that research in this area should be increased in SEA by adding 0.5 scientist year at Durant.

The new scientists selected to implement priorities 2, 3, and 5 should be trained in limnology (aquatic biology) and phycology.

Subcommittee members:

P. C. Quimby, Jr., USDA, SEA, Chairman
E. B. Knipling, USDA, SEA
Carole Lembi, Purdue University
Jesse Lumin, USDA, SEA (NPS)
R. G. Menzel, USDA, SEA, Vice-Chairman and Recorder
Wendell Miller, USDA, SCS
L. D. Moyer, Calif. Dept. of Water Resources
N. E. Otto, Bureau of Reclamation

REPORT OF THE SUB-COMMITTEE ON MECHANICAL CONTROL, HARVESTING AND UTILIZATION OF AQUATIC WEEDS

Magnitude of Aquatic Weed Problems

The U. S. Army Corps of Engineers estimates infestations and potential infestations of the principal aquatic weeds are:

Plant Species	Present Extent of Infestation (acres)	Total Surface Available (acres)	Potential Problem Area (acres)
Waterhyacinth	1,000,000*	38,200,000	9,550,000
Alligatorweed	60,000	39,400,000	9,850,000
Hydrilla	50,000	12,300,000	4,305,000
Waterlettuce	3,000	38,200,000	9.550,000
Watermilfoil	500,000	69,800,000	17,450,000
Egeria	50,000	72,300,000	10,845,000
Waterchesnut	3,000	3,000,000	1,050,000
Total	1,700,000		63,000,000

*Estimates from other agencies or combinations of agencies are considerably higher in these categories.

Impact of Aquatic Weeds

Aquatic weeds have numerous impacts, most of which can be reduced, with various degrees of complexity and accuracy, to economic impacts.

Among these are:

1. Control costs
2. Recreational impairment
3. Property value loss
4. Water loss
5. Channel capacity loss and compensatory overdesign, including probability and cost of catastrophic failure (flooding)
6. Water quality impairment
7. Navigational impairment
8. Commercial fisheries impairment
9. Public health impairment (disease vector habitat)
10. Natural or preferred ecosystem impairment
11. Specialized losses or impairments (e.g. fire protection)

Current Research on Aquatic Weed Problems

SEA has no current research in mechanical control, harvesting or utilization of aquatic weeds. Independent research and development programs have been conducted at several universities and government agencies using intramural, NSF, OWRT, or state or local funding

support. A few manufacturers have developed harvesting and related equipment.

University of Florida researchers have investigated harvesting, processing and utilization of waterhyacinth, hydrilla, and duckweed. Waterhyacinth harvesting concepts have been developed and are being refined. Feed production processes and equipment have been developed and design criteria established for dried and ensiled waterhyacinth and hydrilla. Acceptability, consumption and utilization of nutrients in diets containing waterhyacinth and hydrilla have been found in ruminant animal performance trials. Paper-making characteristics of waterhyacinth have been established. Some soil-amending properties of waterhyacinth have been determined. Use of hydrilla as fish food and decomposition of waterhyacinth and hydrilla are being explored. Use of waterhyacinth for tertiary treatment of sewage effluent has been tested and tertiary treatment by duckweed, with subsequent utilization in a variety of ways, is being investigated.

University of Wisconsin scientists, in cooperation with Dane County, have investigated harvesting, processing and utilization of Eurasian watermilfoil. Harvester and harvesting system development and analysis, including operations analysis, economic analysis and biological examination of harvesting effects, have been a major thrust of their program. They have processed milfoil and produced a leaf protein concentrate, but the results of feeding trials with the fiberous residue were discouraging. They have found that they can dispose of much of the harvested milfoil in urban areas by encouraging use by gardeners as a soil ammendment.

University of Guelph researchers, in cooperation with the Ontario Ministry of the Environment and Limnos, Ltd., have investigated processing and utilization of Eurasian watermilfoil. They found that it could be composted rapidly and that the compost had many desirable characteristics when compared to sphagnum moss. Feed production and utilization research with poultry and cattle yielded more promising results than those at Wisconsin.

Louisiana State University scientists have evaluated the use of duckweed for nutrient uptake from wastewater and subsequent use of the plants, primarily as poultry feed, and found it to have some adavantage over other species.

Workers at Sam Houston State University are beginning a program in utilization of waterhyacinth for nutrient uptake with subsequent harvest and use of the plants.

The U. S. Army Corps of Engineers, with by far the longest experience in mechanized control of aquatic weeds, is well into a new three-phase mechanical control evaluation program. First phase was evaluation of

the commercially-available Aquamarine Aqua-Trio system on waterhyacinth and hydrilla at several locations. Second phase is evaluation of prototype equipment on waterhyacinth and hydrilla at several locations in Florida and determination of site-dependence of system design criteria. Third phase will be development of system designs by potential manufacturers.

The Florida Department of Natural Resources has supported development of two large harvesters and has cooperated with the Florida Game and Fresh Water Fish Commission in evaluation of those and several commerical harvesters.

National Aeronautics and Space Administration researchers have studied use of waterhyacinth and a few other species for water purification and nutrient uptake, with subsequent use of the plants for biogas (methane) production and animal feed. Their interests in this area are operational systems for facility and industrial wastewater treatment and water-nutrient recycling in closed systems (e.g. space stations). One spin-off of the work is the use of waterhyacinth as a concentrating bio-assay for heavy metals in industrial effluents.

The Province of British Columbia is developing harvesting equipment and procedures in connection with a mechanical control program on the Okanogan river system. Government agencies in some of the Asian, African, European, and South American countries have research, and in a few cases, operating programs in utilization and mechanical control of aquatic plants. In a few of these countries, primarily in Asia, aquatic plants are utilized to a much greater degree than in the United States, because of necessity, availability, low labor value, and lack of more desirable resources.

Most visible of the commerical firms in aquatic weed harvesting and utilization is Aquamarine, manufacturer of the well-established Aqua-Trio harvester-transport-shore conveyor system. They have also recently introduced the Hyballer, a harvester which chops and throws, and the Chub, a small, manually assisted harvester. Carver Aquatics makes a waterhyacinth harvester, a submersed weed cutter, and a biomass sampler. Hockney and Air-lec make submersed weed cutters and rakes. Lantana Boatyard makes a destroyer for opening shallow boat trails. Sarasota Weed and Feed has built several prototype waterhyacinth harvesters and makes a commercial mixed potting soil using composted waterhyacinth. Limnos, Ltd. has developed a prototype submersed weed harvester and harvesting techniques in conjunction with their work with the Ontario Ministry of the Environment. Several British, Dutch, German, and Australian firms manufacture mechanical control equipment, primarily ditchbank and submersed weed cutters.

In overview, the present research in mechanical control, harvesting and utilization is poorly focused, largely due to the variety of species, sites, and unexplored potential uses of the plants. Enough of these have been explored that there now is a need for coordination of the efforts to minimize wastefui duplication. Such coordination could reduce overall program costs for everyone involved, improve program effectiveness, enhance inter-disciplinary and inter-institutional communication for more rapid, accurate and comparable results, and reduce confusion among scientists, administrators, and the taxpaying and using public. The one danger of coordination which should be avoided is suppression of innovation and inquiry.

Mechanical control systems are in operational use by several municipalities, counties, lake-front property owners associations, state and federal agencies, and private contractors, in some cases partially as a result of favorable research findings on development. This body of operational uses should be a source of information on costs, impacts and operating techniques.

Current and Future Research Needs

Harvesting is a viable method for control and utilization of aquatic plants. It meets real or perceived needs in situations where (1) presense of any appreciable chemical residue or decaying vegetation are intolerable, as in potable, irrigation, fisheries, or contact recreational water, (2) nutrient removal is a major consideration, (3) it is necessary to remove a large concentration of biomass with minimum lasting environmental damage to begin an integrated (e.g. biological) control-maintenance program, (4) the biomass present has an appreciable economic value, (5) water velocity or other factors interfere with placement and retention of chemical agents, or (6) there is a net cost advantage to harvesting.

The initial purpose of developing uses for aquatic weed species is to reduce or eliminate disposal costs and, if possible, to offset the cost of control. Consideration should be given to the nature and extent of the market for the classes of proposed products. A small market could easily be glutted with consequent price suppression. A valuable product, particularly one subject to quality level on uniformity restrictions, could possibly be more economically produced under aquaculture, to the detriment of control purposes.

Research needed in support of mechanical control-harvesting-utilization fall into categories of (1) basic research, (2) component, device and process development, and (3) systems development.

Basic research needs include (a) determination of chemical constituents, (b) determination of bulk *in situ* physical and mechanical properties, and (c) determination of elemental and bulk as-harvested physical and mechanical properties of the principal problem species

thought to be ammenable to mechanical control harvesting and/or utilization. Some of the principal species have been analyzed for elements and simple compounds, but more detailed analysis, including those for complex organic compounds, and prediction of variability could aid in establishing new utilization potential or limitations. A minimum of 2 SY (analytical chemistry), would be needed for minimum analyses of the principal species and could be done at university biochemistry, organic chemistry, or agricultural chemistry departments or at any of the existing SEA aquatic weed research locations. Data on in situ stand density, buoyancy, and bulk density are available for most species on which harvesting has been attempted. However, reliable in situ statistical data (including variability) that permit the determination of shear, tension, and compression characteristics of the principal harvestable plants are needed to establish the capacity, strength, and energy requirements of harvesters and their components. Similar data are needed for the harvested plants to determine the capacity, strength and energy requirements of processing, transportation and/or disposal equipment. The properties data could be gathered and evaluated in a maximum of 2 SY (Agricultural Mechanical Engineering), by the University of Florida (waterhyacinth and hydrilla) and the University of Wisconsin (milfoil) agricultural engineering departments or by the U. S. Army Corps of Engineers Waterways Experiment Station, who already have some of the simple preliminary data and much of the necessary equipment.

Development of components, devices and processes includes (a) development of mechanical equipment for weed control in Western irrigation ditches and canals and (b) design and evaluation of more effective, more efficient, lower cost harvesting, processing, transportation, utilization and disposal machines, components and processes. In the absence of satisfactory chemicals and chemical techniques for weed control in irrigation ditches and ditch banks, and excessive costs for existing mechanical control procedures, mechanical control equipment should be developed to mow and remove submersed and ditchbank weeds in ditches and canals, and for planting desireable ditchbank and submersed competitive species. The equipment should be adaptable to a reasonable variety of canal sizes and configurations, be able to cope readily with bridges and culverts and have reasonable operating capacities and costs. Development of the numerous types of equipment involved would require at least 5 SY (Agricultural/Mechanical Engineering) and should be the responsibility of an agricultural/mechanical engineer employed by SEA and located at Davis, or employed by the Bureau of Reclamation and located at Denver. Development of machines, components and processes is needed to enhance the economic feasibility of mechanical control. Because expertise is distributed among universities, experiment stations, manufacturers, and independent inventors, responsibility and SY are difficult to assign, but it would be a continuing effort which could best be monitored and, insofar as possible, coordinated by the Corps of Engineers Waterways Experiment Station.

Systems development includes (a) assessment of the magnitude and distribution of physical, economic, social, political and technical impacts of various aquatic weeds, (b) development of an integrated mathematical model of aquatic ecosystems and aquatic weed control systems,

and (c) design and evaluation of a versatile mechanical control-harvesting system.

Estimates used to describe the magnitude and distribution of the various impact parameters are thought by many investigators to be unreliable. Because these estimates are used to justify distribution of operational and research effort, there defensibility should be ascertained and the estimates verified, corrected, updated, substantiated and documented. SEA/FR and ERS should cooperate in the technical-economic evaluation. One SY distributed among biological and econic disciplines should be adequate for the first evaluation, with about 0.1 SY per year, similarly distributed, thereafter for correction and updating, unless serious flaws are found in the supporting technical data.

Development of an integrated mathematical model of aquatic ecosystems will require assembly of relationships and interactions from all the relevant disciplines and, probably, development of new relationships and acquisition of new data to fill gaps disclosed by construction of the model. The model, after it is completed and verified, should be able to predict effects of natural and imposed changes, such as those caused by aquatic weed control programs of all types and mixtures of types. The model could be used to design and evaluate operational scale chemical, biological, mechanical, environmental manipulation, and integrated aquatic weed control systems on any species and site, including biological effects and disposition of the plant residue. The Corps of Engineers Waterways Experiment Station is prepared to lead development of the model. At least 10 SY distributed amongst biological, mathematical and engineering disciplines will be required to assemble a minimal model.

An operational aquatic weed harvesting system should be built and tested under a variety of conditions, collecting adequate data to construct and/or verify that portion of the mechanical model and to determine economic feasibility of mechanical control. Again, the Corps of Engineers Waterways Experiment Station is prepared to lead in harvesting system development. At least 10 SY, including agricultural/mechanical engineers and biologists, will be required for the first round of design and evaluation of the system.

The mechanical control-harvesting-utilization sub-committee recommends the following priorities:

1. Assessment of magnitude and distribution of impacts of noxious aquatic weeds.
2. Aquatic ecosystem-weed control system analysis by mathematical modeling.
3. Determination of chemical, physical and mechanical properties of the aquatic weeds having the greatest potential for harvestability and utilization.
4. Design and evaluation of prototype mechanical systems and use of data for development and verification of the mathematical model.

5. Design and evaluation of components, devices and processes for mechanical systems. This design may be partly a by-product of system design and evaluation.

Subcommittee Members

L. O. Bagnall - UF - Chairman
R. D. Comes - SEA
W. H. Rushing - USACE

Davis, California

1. Primary and related NRP's: Primary NRP 20280, Related NRP 20290

2. Number and title of CRIS Work Unit: 5206-20280-001. Control of weeds and certain other aquatic pests in the Pacific Southwest.

3. Location: Davis, California

4. Scientist's name, address, and telephone number: Peter A. Frank, Plant Physiologist, USDA-SEA, Botany Department, University of California, Davis, California 95616

5. Current SY's: 1 SY

6. Percent of time devoted to weed research: 100%

7. Estimated Unofficial Net Budget:
(1) Salaries $43,600 (2) Operations $15,200

8. Mission of research: Develop methods for management of aquatic vegetation for maximum utilization of water resources for agriculture, municipalities, recreation, fish and wildlife.

9. Objectives of research: Investigate individual and integrated approaches to control of aquatic weeds, including herbicides, biological control agents, and ecological modification. Investigate physiology, ecology, and biochemistry of aquatic plants in order to understand why and how weed problems occur, and how effective control programs can be devised.

10. Status of current research in meeting NRP 20280 objectives: Satisfactory

11. Significant research accomplishments: (1) Developed and demonstrated successful techniques for use of cocoamine derivatives of endothall for control of submersed aquatic weeds in large bodies of water in California. (2) Established an allelopathic relationship between spikerush (*Eleocharis coloradoensis*) and pondweeds and demonstrated the mechanism of competition that exists among these plants in nature.

12. Impact of research accomplishments on science and general public: This research has provided a means by which severe weed infestations in irrigation and municipal water systems and in recreational waters can be managed without excessive hazard to water users or the aquatic environment. How wide the use will eventually be, cannot be predicted.

13. Obstacles to achieving objectives: (a) Lack of a sufficiently broad base of scientists to research aquatic weeds, aquatic weed problems and control methods in the depth required (b) Shortage and lack of adequate facilities such as: research ponds, greenhouses, laboratory and office space. (c) Absence of adequate fundamental research on physiology, ecology, and biochemistry of aquatic plants on which to

develop new and improved aquatic weed control technology (d) Because of our sources of funds (soft money), there are restrictions on latitude and options available in research approaches followed.

14. Future lines of needed weed research and plans for implementation: Only very limited lines of new research are planned for the near future because of personnel ceilings, funding, and inadequate facilities.

15. Research, facilities, and personnel needs: Because the aquatic weed problems are so severe, diverse, and complicated, and there are so few scientists working on these problems, there is not a single area ranging from personnel to facilities that does not need expansion and improvement.

16. Extent of cooperation - names of persons and institutions: University of California, Davis, California; U. S. Bureau of Reclamation, Sacramento, California; California Department of Water Resources, Sacramento, California.

17. Other considerations: ---

18. Recommendations: (a) Reduce the load of paper work so Research Leaders and other scientists can devote more time to research (b) Provide adequate and competent clerical help for RL's and other scientists (c) Eliminate the farce known as "personnel ceilings" (d) Broaden the scope of basic research in aquatic vegetation (e) Provide adequate research facilities such as greenhouses, labs, ponds and equipment (f) Put less reliance on "soft money" for research programs.

19. Titles for the past 3 years: Protocols for Pesticide Research. 1975. Appears in Appendix of EPA Guidelines for Registration of Pesticides. Protocols for aquatic herbicides prepared in 1974 by incumbent collaborating with Dr. D. N. Reimer of Rutgers University.

Bruns, V. F., Demint, R. J., Frank, P. A., Kelley, A. D. and Pringle, J. C. 1974. Responses and residues in six crops irrigated with water containing 2,4-D. Bull. 798, College of Agriculture Research, Washington State University. 9 pp.

Demint, R. J., Pringle, J. C. Hattrup, A., Bruns, V. F. and Frank, P. A. 1975. Residues in crops irrigated with water containing trichloroacetic acid. J. Agr. and Food Chem. 23: 81-84

Herbicide Study. 1975. Report on uses of herbicides to EPA Hazardous Materials Advisory Committee. Section entitled Aquatic Uses prepared by incumbent with some assistance from Dr. C. Walker, Fish and Wildlife Service. pp. 126-150. In Press.

Comes, R. D., Frank, P. A. and Demint, R. J. 1975. TCA in irrigation water following bank treatments for weed control. Weed Sci. 23: 207-210.

Frank, P. A. Competitive interactions among aquatic plants. 1975. Proc. Workshop on Biological Control for Water Quality Enhancement. Gainsville, Florida. Jan. 29-31. pp. 24-27. Review paper.

Frank, P. A. Herbicides in surface waters. 1975. Symposium on Herbicides in the Environment. Proc. California Weed Conference. pp. 14-26.

Frank, P. A. Distribution and utilization research on tropical and subtropical aquatic weeds in the United States. Proc. Regional Seminar on Noxious Aquati Vegetation in Tropics and Subtropics. New Delhi, India, December 12-17, 1973. This review type paper, with a summary of the Utilization Research Workshop and recommendations for future research were accepted May 1974 for publication in the proceedings of the seminar. No copy of the proceedings has been received as yet.

Davis, California

1. Primary and related NRP's: New and Improved Weed Control Technology for Controlling, Managing, or Using Weed Populations to Improve Water Quality, Fish and Wildlife Habitats, and Recreational Areas Aquatic and Non-cropland Sites: 20280. (Related NRP's are: 20260 20300, 20720, 20730, 20790).

2. Number and title of CRIS Work Unit: 5206-20280-001. Control of weeds and certain other aquatic pests in the Pacific Southwest.

3. Location: Davis, California

4. Scientist's name, address, and telephone number: Richard R. Yeo, USDA-SEA, Botany Department, University of California, Davis, CA 95616 Comm. (916) 752-1096 FTS: 453-1096.

5. Current SY's: 1 SY NRP 20280.

6. Percent of time devoted to weed research: 100 percent

7. Estimated Unofficial Net Budget:
(1) Salaries: $40,000 (2) Operations: $15,000

8. Mission of research: To control aquatic weeds.

9. Objectives of research: (1) Investigate individual and integrated approaches to control aquatic weeds, including herbicides, herbivorous fish and other aquatic fauna, insects, competitive plants, pathogens and other organisms. (2) Investigate physiology, ecology, and biochemistry of aquatic plants in order to understand why and how the weed problems occur, and how effective control programs can be devised.

10. Status of current research in meeting NRP 20280 objectives: The current objectives will be continued.

11. Significant research accomplishments: Developed a treatment using a herbicide combination, diquat plus copper sulfate pentahydrate, that controlled dense infestations of filamentous algae in salmon spawning channels and aquatic weeds in farm ponds. Established a seed nursery for the aquatic plant competitor, dwarf spikerush, and developed techniques for harvesting, cleaning, storing, and germinating the seed.

12. Impact of research accomplishments on science and general public: The research has provided inproved flow of water in conveyance systems such as large water transport canals and small irrigation laterals, and reduced vegetation in farm reservoirs, in potable and recreational waters. The final effect has been to increase the amount of water available at a given time, reduce the price of water, and provide water of improved quality.

13. Obstacles to achieving objectives: The only current obstacle is the lack of recognition for the need to search for and study foreign aquatic plant competitors that may be useful in managing aquatic weeds in the United States.

14. Future lines of needed weed research and plans for implementation: None

15. Research, facilities, and personnel needs: None

16. Extent of cooperation - name of persons and institutions: University of California at Davis; U. S. Bureau of Reclamation, Inter-Pacific Region; California Department of Water Resources; and California Department of Fish and Game.

17. Other considerations: None

18. Recommendations: None

19. Titles for the past 3 years:

Yeo, R. R. 1975. Notes on the ecology and distribution of undesirable vegetation in two northern California canals and reservoirs. Symp. on Plant Diversity in Aquatic Habitats. California Native Plant Society.

Yeo, R. R. 1975. Life and death of aquatic weeds: a time-lapse photographic study. Symp. on Plant Diversity in Aquatic Habitats. California Native Plant Society.

Yeo, R. R. and N. Dechoretz. 1975. Diquat and copper ion residues in salmon-spawing channels. Weed Sci. 24:405-409.

Nelson, S. G., A. C. Andersen, M. H. Momeni, and R. R. Yeo. 1976. Test to sterilize sexually undifferentiated fry of *Tilapia zillii* Gerv. (Pisces: Cichlidae) using ^{60}Co gamma-ray irradiation. Progressive Fish Culturists. December.

Yeo, R. R. 1976. Managing aquatic vegetation using antagonistic associations that naturally occur between plants. Proc. 4th Int. Symp. on Biological Control of Weeds. (accepted for publication).

Yeo, R. R. and N. Dechoretz. 1977. Acute toxicity of a herbicidal combination of diquat plus copper ion to eggs, alevins, and fry of rainbow trout and two aquatic macroinvertebrates. Jour. of Aquatic Plant Manag. (accepted for publication in Volume 15)

Yeo, R. R. 1976. Managing aquatic vegetation by plant antibiosis and natural plant growth adaptations . (abstract). Proc. Calif. Weed Conf.

SUMMARY OF SEA AQUATIC-WEED RESEARCH PROGRAM BY SCIENTIST, LOCATION, AND CRIS WORK UNIT

Denver, Colorado

1. Primary NRP: 20280 (Weed Control) Related NRP's: 20280 (Pesticides and growth regulators); 20170 (Physiology and biochemistry-plants); 20740 (Irrigation and drainage) 20760 (Water use efficiency); 20800 (Erosion and sedimentation).

2. Number and title of CRIS Work Unit: Two Units. SEA 5604-20280-002 "Developmental physiology and ecology of aquatic plants", SEA 5604-20280-001 "Fate and mode of action of herbicides used to control aquatic weeds".

3. Locations: Primary - Aquatic Weed Research Lab., DFC, Denver, CO. Field locations U.S.B.R. Field Station, Loveland, CO; various irrigation systems in CO used with permission of cooperators.

4. Scientist name, address, phone number: Lars W. J. Anderson, PhD, (Plant Physiologist, Research Leader, P. O. Box 25007, DFC, Denver, CO, 80225.) FTS: 234-4132 COM: 303-234-4132.

5. Current SY's: One 100% to 20280

6. Percent time on weed research: 90%, 10% on managerial and administrative duties.

7. Estimated unofficial budget: Salary - $77,000. All other - $26,000.

8. Mission of Research: To develop and improve methods for controlling aquatic weeds which are detrimental to the efficient production of irrigated food and fiber crops. Means of weed control examined include chemical, water-level fluctuation and competitive interactions with non-detrimental aquatic weeds: This mission compliments aquatic weed research undertaken at other SEA locations in Davis, CA, Prosser, WA, and in Ft. Lauderdale, FL. Success of the mission ultimately leads to reduced losses of irrigation water and therefore reduction in the proportion of capital utilized in production of irrigated crops.

9. Objectives of Research: a. Examination and identification of growth, development and propagation mechanisms in aquatic weeds. Specifically,environmental and physiological factors affecting overwintering and vegetative propagation of American Pondweed and Sago Pondweed are examined. (These are two of the major aquatic weeds in Western irrigation systems.) By understanding the regulation of growth, development and propagation, it is anticipated that physiological "control points" may be elucidated which are amenable to manipulation by chemical, biological or physical means. b. Small-plot testing of the fate of herbicides applied to irrigation water. Herb-

icide residues in irrigated crops are determined as part of the establishment of acceptable tolerances by the EPA, c. Identification and evaluation of potential new herbicides. This is accomplished through a primary herbicide screening program in which efficacy against American & Sago pondweed, and *Elodea* is examined in greenhouse studies. d. Field evaluation of promising aquatic herbicides or weed control methods. Applications are made to irrigation or drainage ditches for assessment of weed control under typical environmental conditions. Studies are often combined with herbicide residue analysis in water and soils. e. Elucidation of the mode of action of aquatic herbicides and their movement (translocation) in plants. This knowledge helps identify potential control points and aids in our understanding of the types of compounds which may have potential growth-regulating capacity. f. Improve methods for controlling problem algae by developing a screening program and mode of action analysis program. This objective is designed to broaden the scope of aquatic plant control research to encompass algal species that are economically important weeds in irrigation system.

10. Status of current research: The objectives outlined above (item 9) are being, and will continue to be pursued in a parallel manner. All objectives are interrelated and contribute to the overall NRP goal of improving weed control. The budgetary and manpower expenditures are divided approximately equally between (1) field and greenhouse screening and residue work and (2) basic research on aquatic weed biology. It is anticipated that our efforts directed toward algae control will be increased since this is a new objective which has not received significant attention here. It is felt that such a multifaceted approach provides the best possible opportunity for developing methods and practices for control of aquatic weeds.

11. Significant research accomplishments in past three years: (a) Analysis of the dissipation rate of the herbicide dalapon in moving water, and residue of dalapon in crops irrigated with dalapon-treated water. Data from these studies was submitted to the EPA in support of a petition for registration of dalapon for use on irrigation systems. (b) Dissipation behavior of the herbicide glyphosate in slow-moving earthen canals and a fast-moving cement-lined canal. These data were submitted to the EPA to support a petition for an experimental permit for the use of glyphosate on irrigation systems. (c) Preliminary studies have indicated that the aquatic plant, slender spikerush, may produce a compound which is inhibitory to the growth of problem aquatic weeds. Further investigation may help establish whether or not this plant can be used successfully as a biological means of controlling detrimental aquatic plants. (d) Studies on the reproductive physiology of American pondweed have shown that nutritional relationship in the plant are altered by removal of vegetative daughter plants or rhizomes. Understanding these relationships may enable one to apply control measures at the most optimal time for plant-kill. (e) A study on the ecological effects of herbicide application to a small pond is nearing completion. A treated pond and a comparable untreated pond were monitored for changes in water quality and species composition over several months following herbicide application. Data derived from this study help establish the sensitivity of such ecosystems to herbicide treatment.

(f) Development of a technique for assessing the uptake rate of aquatic herbicides through isolated American pondweed epidermal issues. Using this method, the transport behavior of several aquatic herbicides was determined in an effort to understand differences in efficacy of the compounds. (g) Development of a technique for partitioning aquatic plants in order to study the relative nutritional contribution of foliage and roots. This method may yield useful information on means of controlling growth by interfering with uptake of nutrients. (h) Analysis of residues of the broadleaf herbicide 2,4-D in irrigation water and in crops irrigated with 2,4-D-treated water. These data were submitted to EPA as part of a petition to obtain registration for 2,4-D on irrigation ditchbanks.

12. Impact of research accomplishments on science and general public: It is estimated that annual losses contributable to aquatic weeds in irrigation systems amount to $42,000,000. Approximately $25,000,000 is spent on control of these weeds. If, as a conservative estimate the impacts of research conducted (outlined below) reduced cost and losses by only 1%, this would yield a savings of over $600,000 per year. Impacts are the following: (a) EPA accepted a petition for an experimental permit for use of glyphosate on ditchbanks (July 28, 1976). (b) EPA registered a label and accepted a tolerance for 2,4-D (dimethylamine salt) for use on ditchbanks (March 6, 1975). Residue data was requested by and sent to seven other 2,4-D packagers. (c) A petition for registration and tolerance for dalapon was submitted to EPA in July, 1976. The outcome of this application is pending. (d) Environmental effects studies, such as the glyphosate application on a small pond have direct benefit to protection of the aquatic environment. (e) Information derived from physiological studies may allow for optimization of dosage rates and timing of applications to reduce the quantities of herbicides required for control of aquatic weeds.

13. Obstacles to achieving objectives: (a) Limited knowledge of growth and developmental mechanism in pondweeds, particularly over-wintering control mechanisms. (b) Lack of information on transport (uptake) of herbicides. (c) Lack of adequate professional support to carry out our multi-objective program. (d) Lack of adequate laboratory technician support. (e) Lack of adequate clerical support to handle manuscripts and routing administrative correspondence. (f) Lack of adequate greenhouse space (now sharing with Bureau of Recl. personnel and Fish and Wildlife personnel).

14. Future lines of needed research: (a) Emphasis on research to elucidate control of over-wintering processes in pondweeds. Examination of physiological changes during formation and germination of over-wintering buds is planned. (b) Increased effort in algae control methods. Culture facilities are being set up for this work. (c) Evaluation of newly developed controlled-release herbicide formulations to determine applicability to irrigation weed problems.

15. Research, facility and personnel needs: Laboratory professional and technical personnel are needed to adequately address the objectives outlined above. An additional SY and 2 technicians MY's are needed. An additional greenhouse would facilitate research on developmental physiology.

16. Extent of cooperation: (a) Cooperative Program with Bureau of Reclamation and Fish and Wildlife Service. (b) Cooperation with local irrigation district personnel for field sites.

17. None

18. Recommendation: (a) Increase professional staff by 1 SY in chemistry or biochemistry. (b) Increase technician staff by 2 MY's. (c) Construct a new greenhouse facility to allow for exclusive SEA use. (d) Increase funding by 25% to support additional MY's.

19. Publications: Anderson, L. W. J. 1976. Status of Classification of Aquatic Herbicides. J. Aquat. Plant Mgt. 14:1-3.

Anderson, L. W. J. and B. M. Sweeney. 1976. Diel changes in the sedimentation of Ditylum brightwell:, a marine centric diatom: Changes in cellular lipid and effects of respiratory and ion-transport modifiers. Limnol. and Oceanogr. (in press).

Anderson, L. W. J., H. L. Dozier, W. C. Grosse, W. S. Murray. 1974 EPA Compendium of Registered Herbicides Vol. 1: Herbicides and Plant Regulators U. S. G. P. O., Wash. D. C. 400 pp.

Bartley, T. L., J. G. Armstrong, and P. A. Frank. 1974. Some effects of xylene and acrolein on rainbow trout. Weed Sci. Soc. Amer. (Abstract)

Bruns, V. F., R. J. Demint, P. A. Frank, A. D. Kelly, and J. C. Pringle, Jr. 1974. Responses and residues in six crops irrigated with water containing 2,4-D Wash. Agr. Exp. Sta. Bull. 798.

Comes, R. D., P. A. Frank, and R. J. Demint. 1975. TCA in irrigation water after bank treatments for weed control. Weed Sci. 23:207-210.

Demint, R. J., J. C. Pringle, Jr., A. Hattrup, V. F. Bruns, and P. A. Frank. 1975. Residues in crops irrigated with water containing trichloracetic acid. J. Agr. Food Chem. 23:81-84.

Demint, R. J. and P. A. Frank, 1974. Mode of Nutrient uptake by submersed aquatic plants. Weed Sci Soc Amer. (Abstract).

Pringle, J. C. and R. W. Schumacher. 1976. Movement of Herbicides into Aquatic Plants. Proc. Weed Sci. Soc. Amer. 21.

Pringle, J. C. and R. W. Schumacher. 1976. Movement of Six Herbicides through Epidermal Membranes. J. Aquatic Plant Mgt. (in review)

Pringle, J. C. and P. A. Frank. 1976. Partitioning aquatic plants for research. (in review).

Schumacher, R. W. 1976. Dalapon Residues in Water and Crops. Proc. Weed Sci. Soc Amer. 106.

Schumacher, R. W. 1976. Glyphosate Residues in Water . Proc. West Soc. Weed Sci. (in review).

Schumacher, R. W. 1976. Glyphosate Residues in Water. Weed Sci. (in reveiw).

Schumacher, R. W. and C. E. Rieck. Soil degradation of metribuzin. Weed Sci. 1975. (in press).

Schumacher, R. W., C. R. Rieck, and L. P. Buxh. Metribuzin metabolism in soybeans Weed Sci. 1975. (in press).

Fort Lauderdale, Florida

1. Primary and related NRP's: 20280, 20260

2. Number and title of CRIS Work Unit. 7615-12230-005

3. Location(s). Fort Lauderdale, Florida

4. Scientist's name, address, and telephone number. (Comm. and FTS).
T. D. Center, Research Entomologist
3205 S. W. 70 Avenue
Fort Lauderdale, Florida 33314

Comm. (305) 583-5541/8 FTS 350-9248

5. Current SY's. 20280 and 20260 (inseparable)

6. Percent of time devoted to weed research. 100

7. Estimated Unofficial Net Budget:
(1) Salaries 40,000 (2) Operations 15,000

8. Mission of research. Biological control of waterhyacinth, one of the world's worst aquatic weeds, is being accomplished using safe and effective insects. Research at this location has developed methods for release, distribution, evaluation, and augmentation of these insects. Biological control of the weed should reduce expenditures for chemical and mechanical control of the weed resulting in savings in cost of irrigation, drainage, and water transportation. These savings should be passed along to the consumer. A direct benefit to the consumer results when waterhyacinth is reduced in recreational areas (fishing, swimming and boating sites).

9. Objectives of research. 1. To introduce the insects, Neochetina eichhorniae, Neochetina bruchi, Sameodes albiguttalis, and others which may be cleared, for control of waterhyacinth. 2. To evaluate the control effect of these species individually and together in different field sites. 3. To determine means of enhancing the degree of control to be obtained, utilizing fungi, chemicals, collection and distribution techniques, and combinations with other animals which attack the weed. 4. To assess other arthropods against other weed species.

10. Status of current research in meeting NRP 20280 objectives. Continue current objectives? Yes. Modify objective? Eventually we may want to broaden our scope to include terrestrial weeds. Redirect program? In the future in accordance with modified objectives. Discontinue some current research? Only as completed.

Higher priority research initiated? Other prospects exist, i.e. control of Hydrilla verticillata, Melaleuca quinquenervia, Schinus terebinthifolius, Ludwigia spp., and other weeds, but they are not adequately under study. Although they would not presently be higher priority due to economic loss, they may become relatively more important as waterhyacinth continues to be reduced.

11. Significant research accomplishments. 1. Individual field sites of the weevil Neochetina eichhorniae, numbered approximately 200 by the end of 1976. Waterhyacinth was reduced in the oldest of these sites, producing results ranging from open water to only slightly smaller plants. Generally, waterhyacinth size and density in the older sites were reduced by about half. 2. Methods were attempted to enhance the effect of Neochetina eichhorniae, and synergistic actions were found between the weevil and the fungus, Acremonium zonatum, the mite, Orthogalumna terebrantis, and the fish, Ctenopharyngodon idella, respectively, in reducing waterhyacinth. 3. Integrated control using 2-4,D and the weevil, N. eichhorniae, was begun. Observations indicate that adult weevils initially leave a treated plot, but return to feed voraciously on the elongated regrowth, cutting the plants back to the waterline. 4. A chemical attractant (kairomone) from broken waterhyacinth petioles was discovered. Populations of N. eichhorniae were increased 8 to 16 fold on plants with broken petioles. This technique increased collecting efficiency, and a cooperating agency used it to collect 33,000 adult weevils for distribution to new sites 5. The weevil, Neochetina bruchi was imported and released in 1974 for control of waterhyacinth. More than 20 sites have been established with this weevil, and a large greenhouse colony has been maintained in Fort Lauderdale. 6. The moth, Parapoynx diminutalis, was discovered in Fort Lauderdale (new U.S. record) It feeds heavily on Hydrilla verticillata, one of the worst aquatic weeds. Rearing capability was developed to produce 10,000 eggs/day, and host specificity feeding tests were conducted on 25 aquatic plant species. Although the tests proved the insect is not specific to Hydrilla, it is highly attracted to that plant. In initial field trials, the larvae fed heavily only on Hydrilla in a mixed field stand of Hydrilla and Ceratophyllum demersum.

12. Impact of research accomplishments on science and general public
On public: Research results have been widely accepted, and requests have come from state, national, and international groups for the insects being used for waterhyacinth control.

On science: Principles of population dynamics, plant-insect interactions, synergism from combinations of biological control agents, chemicals involved in host specificity, and new discoveries for biological control have been the major contributions.

13. Obstacles to achieving objectives. Need for laboratory and office space, more permanent technicians, more direct involvement in initiating, developing, and advising the overseas phase(s) of the program.

14. Future lines of needed weed research and plans for implementation. A proposal is presently being written for Australia to begin a survey on *Melaleuca* spp. there to determine whether biological control agents exist. A proposal has been written for Egypt to survey waterhyacinth there and report any potentially useful agents to us. Cooperation has been established with Sudan for a waterhyacinth survey there. These two African countries will also be introducing the weevils from the U.S., and results of these studies should be useful for comparison with results in the U.S. Release of the moth, *Sameodes albiguttalis*, imported from Argentina to combat waterhyacinth, is projected for early 1977. A proposal is being prepared for SEA consideration in releasing this moth.

15. Research, facilities, and personnel needs. Needs include: (1.) An insectary. Plans are underway to modify part of an existing building to serve this need. This is an emergency alternative to constructing a new insectary building. (2.) One additional full time technician, GS-5 level. The current technician (GS-7) is not enough to carry out the full research plan. (3.) An adequate office area. Current space, measuring 6' x 11.5' is barely large enough for the chair, desk, table, and 3 bookcases occupying it. Filing cabinets, reprints, and clerical supplies have to occupy laboratory space, and there is almost no space for seating a visitor.

16. Extent of cooperation - names of persons and institutions. (1.) L. Decell, U.S. Army Corps of Engineers (2.) A. Burkhalter, Florida Department of Natural Resources (3.) W. B. Ennis, H. A. Habeck, R. Charudattan, D. L. Sutton, University of Florida (4.) D. Martin, University of South Florida (5.) G. Baker, Central and Southern Florida Flood Control District (6.) E. Del Fosse, Lee County, Florida, Hyacinth Control District

17. Other considerations. A future provision for continuity needs to be developed in the classical biological control approach such as we are using. As much as 10 years may elapse between initiation and termination of a project, but support may come in turn from PL 480, U.S. Army Corps of Engineers, Florida Department of Natural

Resources, and SEA, with no assurance that the kind of research they will support is ideal for a properly conducted program. It may be well to make 10-year proposals or plans in the future.

18. Recommendations. (1.) Improve publication system of SEA. Currently, we pass a manuscript through 5 separate reviews, 5 rewritings, and require from several months to a year or more between initial writing and publication. It discourages University co-authors and delays getting research information to interested scientists. (2.)Develop long-term (i.e. 10+year) total research plans rather than support mainly 2-4 year proposals on a limited phase of research. (3.) Reduce constraints on individual programs in personnel, travel, working space, funds, and communications, where these items are basic in carrying out research objectives using a specific discipline.

19. Titles for the past 3 years.

Perkins, B. D. 1974. Arthropods that stress waterhyacinth. Proc. III Int. Symposium for Biological Control of Weeds. Commonw. Inst. Biol. Contr. Misc. Publ. #8 49-60.

Silveria Guido, A. and B. D. Perkins. 1975. Biology and host specificity of Cornops aquaticum (Bruner) (Orthoptera:Acrididae), a potential biological control agent for waterhyacinth. Environ. Entomol. 4(3):400-404.

Perkins, B. D. and D. M. Maddox. 1976. Host specificity of Neochetina bruchi Hustache (Coleoptera:Curculionidae), a biological control agent for waterhyacinth. J. of the Aquatic Plant Management Soc. 14:59-64.

Perkins, B. D., M. M. Lovarco, and W. C. Durden. 1976. A Technique for collecting adult Neochetina eichhorniae Warner (Coleoptera:Curculionidae), for waterhyacinth control (Note). The Florida Entomologist (In Press).

Del Fosse, E. S., D. L. Sutton, and B. D. Perkins, 1976. Combination of the mottled waterhyacinth weevil and the white amur for biological control of waterhyacinth. J. of the Aquatic Plant Management Soc. 14.

Del Fosse, E. S., B. D. Perkins, and K. K. Steward. 1976. A new U. S. record for Parapoynx diminutalis (Lepidoptera:Pyralidae), a possible biological control agent for Hydrilla verticillata (Note). The Florida Entomologist 59(1):19-20.

Abstracts are not listed.

Ft. Lauderdale, Florida

1. Primary and related NRP's: 20280, 20290, 20740

2. Number and title of CRIS Work Unit: 7615-12230-004 Physiology and chemical control of aquatic weeds; 7615-12230-002 Physiology, ecology, and management of aquatic vegetation.

3. Location(s). USDA, SEA
Aquatic Plant Management Laboratory
3205 S. W. 70 Avenue
Fort Lauderdale, Florida 33314

4. Scientist's name, address, and telephone number. (Comm. and FTS).
Kerry K. Steward
USDA, SEA
Aquatic Plant Management Laboratory
3205 S. W. 70 Avenue
Fort Lauderdale, Florida 33314

(305) 583-5541, 48; (FTS) 350-9248

5. Current SY's. 1.0

6. Percent of time devoted to weed research. 75%

7. Estimated Unofficial Net Budget: (Location)
(1) Salaries 119,000 (2) Operations 128,000

8. Mission of research. To develop recommendations for the control and management of aquatic weeds that interfere with the efficient utilization of water resources for agriculture, flood control, navigation, fish and wildlife management, and recreation.

9. Objectives of research. 1. To develop basic information on nutritional requirements of aquatic plants including the means of uptake and translocation of mineral nutrients and organic substances. 2. To determine ecological requirements of problem species in regard to light, temperature, soil substrate, water quality and other parameters; determine which of these parameters may be manipulated to produce habitats unfavorable to undesirable vegetation or to encourage development of desirable species. 3. To identify weak links in the life

cycles of problem weeds that may make individual species amenable to management. 4. To evaluate chemicals in the laboratory and field for efficacy in selective removal or growth regulation of problem weed species. 5. To develop more efficient methods of measuring phytotoxic or growth modifying responses of aquatic plants to chemicals to decrease the time and cost required for evaluation. 6. To improve technology of chemical aquatic weed control in flowing water by investigating relationships between concentration and contact time of chemicals, of absorption, translocation and accumulation of chemicals and how these factors affect plant growth.

10. Status of current research in meeting NRP 20280 objectives. General objectives and goals remain the same, the specific objectives are altered annually.

11. Significant research accomplishments. a.) Developed a technique of controlling certain submersed aquatic weed growths in areas of limited water exchange through controlling regrowth with chemical retardants. b.) Assisted in the development of efficacy and residue data to support registration of glyphosate for use in ditchbank weed control. c.) In the course of investigating relationships between eutrophication and aquatic weed proliferation if was determined to be unfeasible to improve water quality in South Florida canals by renovating wastewater in the Everglades marshes.

12. Impact of research accomplishments on science and general public. Phosphrous nutrition studies of Hydrilla demonstrated a low phosphrous requirement. Tissue analyses of widely collected field samples indicated that environmental levels of required nutrients were nonlimiting and contributed to nuisance growths. Studies of Hydrilla reproduction indicated that inability to maintain control of this plant was due to rapid regrowth from vegetative propagules resistant to recommended herbicides. Techniques of maintaining control through control of regrowth with chemical retardants are in final stages of experimental field testing. This technique has potential of eliminating Hydrilla in water bodies with limited water exchange.

    Laboratory and field testing of glyphosate has produced information being used to support registration for use of this herbicide for ditchbank weed control.

The results of research on techniques of applying aquatic herbicides as invert remulsions in polymers or as controlled release formulations has potential for reduced cost and environmental damage.

The results of ecological and physiological studies of Everglades vegetation indicated that capacity of the marshes for nutrient assimilation was limited. This information was utilized in an Environmental Impact statement recommending against disposal of sewage effluents in the marshes.

13. Obstacles to achieving objectives. There are no insurmountable technical obstacles to achieving the objectives listed under Item 9. Additional technical support would increase productivity in the area of herbicide evaluation research.

14. Future lines of needed weed research and plans for implementation. Objectives 1, 2, 3, 5 and 6 are modifications of older lines of research or are new lines which will be initiated as time and manpower permits. The skills of a limnologist are needed to investigate the consequences to the aquatic environment of chemical weed control.

15. Research, facilities, and personnel needs. Research facilities are adequate for achievement of present objectives. A miniature canal system would be useful to investigate effects of flowing water on various control procedures.

16. Extent of cooperation - names of persons and institutions.

Dr. Alva Burkhalter
State of Florida, Dept. of
Natural Resources, Bureau of
Aquatic Plant Research and Control

Mr. Bill Brennan
Central and Southern Florida
Flood Control District

Dr. Wm. B. Ennis, Jr.
Univ. of Florida, Institute of Food
and Agricultural Sciences, ARC
Fort Lauderdale

Mr. Louis Decelle
Vicksburg, Mississippi
U. S. Dept. of the Army
Corps of Engineers

17. Other considerations. None.

18. Recommendations. Improvement of the SEA research program in Aquatic Weed Control would be improved by implementing the recommendations given for NRP 20280 under the MAPS system. The management of my own research could be improved by providing instructions and training for research managers.

19. Titles for the past 3 years.

Steward, Kerry K. 1973. Evaluation of Plant Growth Inhibitors for Control of Hydrilla Regrowth. Abstract, Proceedings, Annl Meeting So. Weed Sci. Soc., New Orleans, La., Jan 17. p. 375.

Steward, Kerry K. 1973. The Phosphorus Nutrition of Hydrilla. Abstract. Proceedings, Weed Sci. Soc. Amer. p. 35

Steward, Kerry K. 1973. Slow Release Formulations for the Control of Aquatic Weeds. Presented in: "Symposium on Application Techniques for Aquatic Weed Control", Proceedings, Annl. Meeting Weed Sci. Soc. Amer. Atlanta, Georgia, Feb 7.

Steward, K. K. and W. H. Ornes. 1973. Assessing the Capability of a Natural Marsh Environment for Renovating Wastewater. Abstract. Proceedings, 36th Annual Meeting Amer. Soc. Limnology and Oceanography. Salt Lake City, Utah. June 10-14

Steward, Kerry K. 1973. Inorganic Nutrient Utilization by Aquatic Vegetation of the Florida Everglades. 100 p. A Technical Research Report submitted May 1973 to the South Florida Environmental Project for transmittal to the Secretary of the Interior.

Steward, Kerry K. 1974. Growth of Hydrilla in Solution Culture at Various Nutrient Levels. "Quarterly Journal" Florida Academy of Sciences, 36(2-4): 228-233.

Steward, Kerry K. 1974. Physiological, Edaphic and Environmental Characteristics of Everglades Sawgrass Communities, 34-46. In "The Ecology of South Florida: Present and Past.", Miami Geological Society Memoir No. 2. 452pp., Miami, Fla.

Steward, Kerry K. and W. Harold Ornes. 1975. The Autecology of Sawgrass in the Florida Everglades. Ecology 56:162-171.

Steward, K. K. and W. H. Ornes. 1975. Assessing a Marsh Environment for Wastewater Renovation. J. Water Pollution Cont. Fed. 47:18 0-1891.

Gainesville, Florida

1. Primary and related NRP's: Primary NRP 20260 and NRP 20280.

2. Number and title of CRIS Work Unit: 7602-12230-002, Identification of Insects for Biological Control of Aquatic Weeds.

3. Location: Biological Quarantine Facility, Gainesville, Florida.

4. Scientists's name, address, and telephone number:

   G. Buckingham, Research Entomologist, Research Leader
   USDA-SEA-SE, Biological Control Laboratory
   P. O. Box 1269, Gainesville, FL 32602
   Comm.: (904) 372-3505 FTS: 946-7271

5. Current SY's: 1 SY

6. Percent of time devoted to weed research: 100% (at present).

7. Estimated unofficial net budget: Salaries = $59,000, Operations = $48,000.

8. Mission of research: Identify candidate insects to control aquatic weeds and evaluate their suppressive capabilities, with special emphasis on waterhyacinth, hydrilla, and eurasian watermilfoil.

9. Objectives of research:
   (1) Clear South American insects for the control of waterhyacinth.
   (2) Test European insect, *Parapoynx stratiotata*, for possible use in controlling Eurasian watermilfoil.
   (3) Investigate biological control potential for the submersed aquatic weed, hydrilla.

10. Status of current research in meeting NRP 20280 objectives: The third insect introduction for the control of waterhyacinth is now undergoing final clearance procedures. Our laboratory feels that, based on available data, this insect species, *Sameodes albiguttalis*, will have a decided impact on the abundance of waterhyacinth in the U. S. With objective number one realized, more effort is being applied to objectives two and three.

11. Significant research accomplishments:
    (1) Contributed to research program on the biological control of alligatorweed. This program has resulted in the reduction of alligatorweed over all its range in the southeastern U. S.

11. (Continued)

(2) Conducted ecological studies on waterhyacinth and its insect enemies. Research that lead to the introduction of Sameodes albiguttalis is expected to return a high cost: benefit ratio.
(3) Data has been gathered on the effects of the introduced weevil, Neochetina eichhorniae, and the native moth, Arzama densa, on waterhyacinth. This information is basic to o biological control of waterhyacinth program and will be used by researchers working on waterhyacinth in the U.S. and elsewhere.

12. Impact of research accomplishments on science and the general

Research on the biological control of alligatorweed has reduced the cost of control from about $50 per acre per year to $0.46 per acre per year if research costs are amortized over a ten year period. The introduction and establishment of three insect species for alligatorweed control has resulted in a control system that now needs only minimal assistance from man.

Recent efforts on the biological control of waterhyacinth have resulted in a request for a permit to introduce a moth, Sameodes albiguttalis, into the U.S. for waterhyacinth control. The larvae of Sameodes bore into the waterhyacinth petioles, inflicting serious damage to the plant. Tests on the host range of this insect species show that it will only feed to a minor extent on other plants, and these are close relatives of waterhyacinth.

Approximately $15 million was spent in Florida alone in 1976 for aquatic weed control. It has been estimated that 35,000 gallons of 2,4-D were used for waterhyacinth control in Florida in 1976. Successful biological control is providing a better less expensive method of aquatic weed control that reduces our dependence on high energy consuming methods.

13. Obstacles to achieving objectives: Our primary obstacle in biological control is the inability to travel overseas as program needs arise. Since travel plans are made up to a year in advance, program travel must be "crystal balled." Biological control efforts would be enhanced if those researchers doing the work could, if the need arises, travel overseas (at short notice) work on possible biocontrol agents. Foreign laboratories would be used for bases when possible. Travel on such a basis would be controlled by the region in conjunction with the National Program Staff.

14. Future lines of needed weed research and plans for implementation:

Increased support has been given to biological control of insect pests and weeds. Careful choice of target species is important at this time. Consideration should be given to the addition of a plant pathologist and insect pathologist to the overseas research effort.

15. Research, facilities, and personal needs: See Item #14.

16. Extent of cooperation - names of persons and institutions:

Florida Department of Agriculture and Consumer Services
Florida Department of Natural Resources
U.S. Army Corps of Engineers
University of Florida

17. Other considerations: Classical biological control is a specialized method of insect pest and weed control that involves the importation and utilization of counterpests (parasites, predators, and/or pathogens). Introduced pests that have been separated from their natural controls are the best targets. For biological control to be economical the target should be the major problem in the agroecosystem in which it occurs. As an example, if a preemergence herbicide is applied to land used for cotton to control ten weed species and biological control removes one of those weeds herbicides will still be necessary to control the remaining nine weed species. Successful biological control of an introduced pest species is an economical, environmentally safe method of pest control. For introduced pests that are the principal pest of an agroecosystem, biological control should be the first method of pest control investigated. Alternative methods should be used to control only those pests above the economic threshold that are not controlled by biological methods. Pest control by biological methods often goes unrecognized. The method may be slow, subtle, and difficult to differentiate from other factors that may have come to bear on the pest problem; factors such as weather, new cultural practices, crop varieties, etc. Business interests, unless they are involved with pest management, do not derive income from biological control, and in fact, alternatives such as pesticides usage may be reduced because of biological control. Thus biological control may be unrecognized outside of the scientific community and we can expect no lobbying from special interest groups for research in this area. Therefore, we must look to government at both the state and the federal level for support of this important method of pest control. Historically, support for biological control has been minimal, often as with the case of waterhyacinth and of gypsy moth, biological control

17. (Continued)

was only funded when it became apparent that the problem created by the pest was not being adequately controlled by other methods. The reduction in the use and availability of pesticides has redirected our awareness to these more ecologically sound methods of pest control.

Pest problems can be better managed. Team efforts towards solving our pest problems in the United States through the development of a multiplicity of controls can provide long-term pest control that is ecologically safe and economically sound. Support for biological control and other alternatives to our commonly used chemical methods of pest control must be the responsibility of our large research agencies such as the Agricultural Research Service of the U.S.D.A.

18. Recommendations: Research can be improved by careful choice of targets for biocontrol research and the assignment of research teams involving different disciplines to a pest problem.

19. Titles of publications for the past 3 years: (selected)

Spencer, N. R. 1973. Insect enemies of aquatic weeds. Proc. 3rd Int. Symp. Biol. Contr. Weeds, pages 39-47 (conference proc.).

Spencer, N. R. and M. Lekic. 1974. Prospects for biological control of eurasian watermilfoil. Weed Sci. 22:401-404.

Spencer, N. R., B. D. Perkins, F. D. Bennett, and E. O. Gangstad. 1974. Insect enemies of aquatic weeds. Aquatic Plant Contr. Prog., Tech. Rep. 6, U.S. Army Corps Eng., WES, Vicksburg, MS, pages D3-D21.

Gangstad, E. O., N. R. Spencer, and J. A. Foret. 1975. Towards integrated control of alligatorweed. Hyacinth Contr. J. 13:30-33.

Spencer, N. R. and J. R. Coulson. 1975. The biological control of alligatorweed. Pages 36-43 in P. L. Brezonik and J. L. Fox, eds. Proc. Symp. Water Quality Management Through Biol. Contr., Rep. No. ENV-07-75-1, EPA/ University of Florida.

Spencer, N. R. and J. R. Coulson. 1976. The biological control of alligatorweed, *Alternanthera philoxeroides*, in the United States of America. Aquatic Bot. 2:177-190.

Prosser, Washington

1. Primary and related NRP's: 20280, 20260, and 20790

2. Number and title of CRIS Work Unit. 5806-20283-001; Control of Weeds in Aquatic and Noncrop Areas in the Pacific Northwest

3. Location(s). Prosser, Wapato, Sunnyside, Washington

4. Scientist's name, address, and telephone number. Richard D. Comes, Weed Scientist, Plant Physiologist, Irrigated Agriculture Research and Extension Center, Prosser, Washington 99350. Telephone No. 509-786-3454

5. Current SY's. 20280-.7SY; 20260-.2SY; 20790-.1SY

6. Percent of time devoted to weed research. 100%

7. Estimated unofficial net budget:
   (1) Salaries $46,800   (2) Operations $10,550

8. Mission of research. The development of principles and practices for controlling weeds and managing vegetation in and around water without causing undesirable effects on humans, livestock, fish, wildlife, and economic crops.

9. Objectives of research.

   (1) Study the seedling vigor, adaptability, growth habit, competitive ability, and herbicidal tolerance of selected perennial grass species and plant introductions for suitability as replacement vegetation on weedy ditchbanks.

   (2) Develop management practices that will provide long-term weed control on ditchbanks with minimal use of herbicides, and that will decrease evapotranspiration rates without causing soil erosion problems.

   (3) Evaluate herbicides for the control of specific submersed, emersed, and ditchbank plants that create problems with water delivery and drainage in the Pacific Northwest.

   (4) Determine the effects and residues of herbicides used in and around water on economic plants irrigated with water bearing the herbicides.

10. Status of current research in meeting NRP 20280 objectives.

    Objectives: It is planned to continue the current objectives of my research until the goal is obtained. Methods of effectively, safely, legally, and economically managing vegetation on ditchbanks is the most urgent weed control need of irrigation projects in the Pacific Northwest.

11. Significant research accomplishments. Eighteen selections of reed canarygrass collected from a wide geographical area varied widely in their growth habit, sexual and asexual reproductive capacity, and in their response to certain herbicides when grown at a common site. Seedlings of redtop and creeping red fescue (Boreal variety), grasses suited for replacement vegetation on ditchbanks, were found to be considerably more tolerant of four herbicides than was reed canarygrass. Stands of creeping red fescue seedlings were reduced only slightly while reed canarygrass seedlings were nearly eliminated by 1 lb/A of glyphosate. Established creeping red fescue plants (Boreal variety) were more susceptible to glyphosate than were seedlings, and established reed canarygrass responded in an opposite manner. Of 62 plant introductions and four named varieties of creeping red fescue (including Boreal), introductions from Poland, the Netherlands and Canada were most tolerant of glyphosate applied to established plants at 2 lb/A. Methods of applying acrolein at a concentration of 45 ppb to 400 cfs of water accurately and over a long period of time and of detecting 5 ppb of acrolein in water were developed. Glyphosate applied to vegetation on dry irrigation canal banks did not produce a residue in the water when the canals were filled. When glyphosate was injected directly into flowing water, 30 percent of the glyphosate was lost in the first mile, but only about 12 percent was lost in the next 4.5 to 8 miles. Six crop plants furrow or sprinkler-irrigated with water containing glyphosate at concentrations up to 2.2 ppmw for 8 hours (1.0 lb/A) were not injured nor did they contain herbicide residues at harvesttime.

12. Impact of research accomplishments on science and the general public. Methods of managing vegetation on ditchbanks have been developed that result in a stable, attractive ditchbank that is safer for irrigation operation and maintenance personnel and that could reduce operation and maintenance costs $5,000,000 per year. The methods were adopted by many irrigation projects, but lack of use of registrations for the herbicides that were utilized as a part of the management program have forced managers to discontinue the program. Research on herbicide residues and dissipation in water, soils, and plants have aided in obtaining registration for one herbicide and in obtaining an experimental permit for another. Such studies have also shown that two herbicides that were efficacious and economical were not environmentally acceptable for use in or around irrigation water.

13. Obstacles to achieving objectives. Technical obstacles to progress in my research primarily involve the lack of registration of herbicides for use on irrigation delivery ditchbanks. Considerable time, money, and effort have been spent in obtaining data that was required for registration, only to find out the next year additional data is required. With the exception of glyphosate, commercial companies are willing to cooperate, but

do not give herbicides suited for this use a very high priority because of the minor use and because patent rights have expired on most of the potential herbicides for ditchbank use. If we had the chemical tools available today that we had in 1960. plus glyphosate, I believe several of my current objectives could be attained in a relatively short time. Lack of scientific knowledge concerning the physiology and ecological requirements of submersed species is a severe handicap in developing improved methods of controlling or managing these types of plants. There are no administrative obstacles to achieving my objectives. Technical support and funds are adequate for the first time in the past 7 years. Additional field research facilities, especially mini-canals and ponds are needed to provide field sites under our control.

14. Future lines of needed weed research and plans for implementation. New lines of research would be undertaken to develop application equipment, seeding equipment, and mechanical control devices and to breed and select plants for replacement vegetation on ditchbanks and in the bottoms of canals, reservoirs and lakes if additional scientific manpower and funds were available.

15. Research. facilities and personal needs. (See item 13)

16. Extent of cooperation - names of persons and institutions. Washington State University, Irrigated Agriculture Research and Extension Center- Dr. Lin Faulkner, Superintendent; Wapato Irrigation Project - Mr. Judd Alsop, Manager; Roza Irrigation Project - Mr. Henry Vancik, Manager.

17. Other considerations. None

18. Recommendations. Better coordination between researchers working in a given problem or commodity area should strengthen each researcher's work, lead to more team research between locations, and thus strengthen the SEA programs. To accomplish this, Technical Advisors should have responsibility for a certain problem area(s) or commodity(s) across regions, and they should have more leadership (coordination) responsibilities rather than serving this function primarily in an advisory capacity.

19. Titles of publications for the past 3 years.

Bruns, V. F., J. M. Hodgson, A. D. Kelley, and R. D. Comes. 1976 Responses and residues in certain crops irrigated with water containing fenac. Wash. State Univ., Coll. of Agric. Research Center Bulletin 828. 8pp.

Comes, R. D. 1974. Control of reed canarygrass on ditchbanks with glyphosate. (Abstract) 1974 Meeting of the Weed Sci. Soc. of Amer. p. 116.

Comes, R. D., V. F. Bruns, and A. D. Kelley. 1976. Residues and persistence of glyphosate in irrigation water. Weed Sci. 24(1): 47-50.

Comes, R. D., P. A. Frank, and R. J. Demint. 1975. TCA in irrigation water after bank treatments for weed control. Weed Sci. 23(3): 207-210.

Comes, R. D. and A. D. Kelley. 1976. Effect of four herbicides on the stand of 22 reed canarygrass selections. (Abstract) Western Soc of Weed Sci. Research Progress Rpt. 181-182.

Comes, R. D. and A. D. Kelley, 1976. Response of rainbow trout and two pondweeds to several concentrations of acrolein. (Abstract) Western Soc. of Weed Sci. Research Progress Rpt. 78-80.

Timmons, F. L. and R. D. Comes. 1975. Studies on the control of sedges (Carex spp.) in farm ditches and along irrigation systems. Wyo. Agric. Exp. Sta. Research J. No. 89. 17pp.

Prosser, Washington

1. Primary and related NRP's: 20280, 20170 and 20290

2. Number and title of CRIS Work Unit. 5806-20283-001; Control of Weeds in Aquatic and Noncrop Areas in the Pacific Northwest

3. Location. Prosser, Washington

4. Scientist's name, address, and telephone number. Louis Y. Marquis, Plant Physiologist, Irrigated Agriculture Research and Extension Center, Prosser, Washington 99350, Comm. 509-786-3454, Ext. 171

5. Current SY's. 20280-.5SY; 20170-.4SY; 20290-.1SY

6. Percent of time devoted to weed research. 100%

7. Estimated unofficial net budget:
   (1) Salaries $33,500 (2) Operations $10,550

8. Mission of research. The development of principles and practices for controlling weeds and managing vegetation in and around water without causing undesirable effects on humans, livestock, fish, wildlife, and economic crops.

9. Objectives of research.

   (1) Study the absorption, translocation, and metabolism of herbicides and plant growth regulators in submersed, emersed and ditchbank plants.

   (2) Evaluate the relative importance of roots and foliage in the uptake of nutrients by submersed plants. Determine the minimum levels of nutrients in the aquatic environment required for growth and development.

   (3) Investigate possible allelopathic interactions between aquatic species.

10. Status of current research in meeting NRP 20280 objectives.

    I am initiating a new program in aquatic weed physiology and plan to work on the objectives listed in item 9.

11. Significant research accomplishments. I recently joined (October 1, 1976) and as yet have not generated any significant results.

12. Impact of research accomplishments on science and the general public.

    In the future, I hope that any knowledge gained on the basic physiology and biochemistry of aquatic plants will be useful to other workers in developing new and more efficient methods of controlling aquatic weeds.

13. Obstacles to achieving objectives. The only problems that I perceive as potential obstacles are a shortage of laboratory space and poor library facilities. However, if operational funds drop below the level listed in item 7, funding would become an obstacle to achieving research objectives.

14. Future lines of needed weed research and plans for implementation. See item 9.

15. Research, facilities, and personnel needs. See item 13.

16. Extent of cooperation - names of persons and institutions.

Dr. Lin Faulkner, Superintendent, Washington State University, Irrigated Agriculture Research and Extension Center, Prosser, WA 99350

17. Other considerations. None

18. Recommendations. SEA research could be improved if SEA would institute a sabbatical leave program. This would enable SEA scientists to broaden their expertise and thus initiate new lines of research more efficiently.

19. Titles of publications for the past 3 years.

Marquis, L. Y. and R. H. Shimabukuro. 1976. Fluchloralin metabolism in soybean. WSSA Abstract. pp. 68-69

Stoneville, Mississippi

1. Primary and related NRP's: NRP-20280

2. Number and title of CRIS Work Unit: 7402-12230-001; Life History and Physiological Studies of Aquatic and Marginal Weeds.

3. Location: Stoneville, Mississippi

4. Scientist's name, address and telephone number: P. C. Quimby, Jr., Plant Physiologist, Biological Weed Control, Southern Weed Science Laboratory, P. O. Box 225, Stoneville, MS 38776; telephone: Com. 601-686-2311, Ext. 243; FTS 497-2243.

5. Current SY's: 1 SY

6. Percent of time devoted to weed research: 100%

7. Estimated unofficial net budget: Salaries: $41,820 per year; Operations: $6,000 per year

8. Mission of research: To improve agricultural production efficiency by developing knowledge about improved protection against losses from weeds.

9. Objectives of research: (1) Conduct life history studies on aquatic weeds in order to improve weed control through a better understanding of their physiological, biochemical, and ecological characteristics. (2) Develop biological and ecological methods of control in order to reduce dependence on herbicides.

10. Status of current research in meeting NRP 20280 objectives: Current objectives will be continued.

11. Significant research accomplishments: (1) We found that growth of alligatorweed, waterprimrose, and smartweed is inhibited by low oxygen or submergence in the dark and is promoted by red light, hydrogen peroxide, or exposure to air (in light or dark). Photosynthesis-inhibiting-herbicides are more effective against submerged than partially submerged plants. (2) We have studied biocontrol of alligatorweed in the Midsouth. The alligatorweed stem borer moth migrated from Florida through Mississippi to Arkansas, Louisiana, and Texas in 1974 and has produced 50 to 90% biocontrol of stable, floating mats in the northern reaches of alligatorweed's range in the Mississippi Valley. This insect and the alligatorweed flea beetle have produced 90 to 99% biocontrol of alligatorweed in the more southern reaches of alligatorweed's range.

12. Impact of research accomplishments on science and general public: (1) The low oxygen inhibition of growth of amphibious weeds has been termed "hypoxic quiescence." Hypoxic quiescence seems to be a fundamental factor in the life history of these plants. If the physiological basis

for this phenomenon can be found, then the knowledge should be very useful in development of new control technology for aquatic weeds. Other scientists should benefit from this research. (2) The alligatorweed insects have destroyed more than an estimated 50,000 acres of this weed in Arkansas, Mississippi, Louisiana, and Texas. Previously, two applications of silvex at 8 lb/A each were required for control at a cost estimated at $40/A with follow-up treatments required. Thus, an estimated $2 million has been saved with an associated and significant saving in energy expenditure for herbicide manufacture and application. The herbicide has been spared for usage on crop land. The environment has benefitted because native plants have been released from competition in many sites and the potential problem of pesticide pollution has been circumvented. Follow-up treatments are unnecessary. The state of Arkansas has cancelled a chemical eradication program and is now relying exclusively on biocontrol of alligatorweed.

13. Obstacles to achieving objectives: A lack of knowledge on the biology of weeds forms the basis for our research program. The development of this knowledge, with time, should help us to achieve our objectives.

14. Future lines of needed weed research and plans for implementation: We plan to study plant/insect relations between waterhyacinth and *Arzama densa*, a native moth. Manipulative augmentation of this moth will be evaluated as a means of controlling or suppressing waterhyacinth. Further, phytotron studies are planned to determine the effect of temperature and light on the growth kinetics of waterhyacinth.

15. Research, facilities and personnel needs: Additional facilities and technical assistance are not necessary for increased effectiveness at the present time.

16. Extent of cooperation: (1) G. B. Vogt, K. E. Frick, S. H. Kay and S. O. Duke, USDA, SEA, Southern Weed Science Laboratory, Stoneville. (2) Jack Tallant, USDA, SEA, Statistician, Southern Region, New Orleans, LA.

17. Other considerations: None

18. Recommendations: I would recommend that the Technical Advisor for aquatic weed research, Dr. P. A. Frank, be provided funds for nationwide travel to more effectively coordinate aquatic weed research throughout the nation.

19. Titles of publications for past 3 years:

Quimby, P.C., Jr. and G.B. Vogt. 1974. Aspects of alligatorweed in the Mississippi Valley. (Abstract) Proc. South. Weed Sci. Soc. 27:280-281.

Quimby, P.C., Jr. 1974. Environmental effects on budbreak of alligatorweed. (Abstract) Abstr. Weed Sci. Soc. Am.:32-33.

Vogt, G.B., P.C. Quimby, Jr., and S. H. Kay. 1975. Alligatorweed biocontrol in the Mississippi Valley. (Abstract) Abstr. Weed Sci. Soc. Am.:34-35.

Quimby, P.C., Jr. and E.L. Robinson. 1975. Calcium oxalate in alligatorweed and silverhead. (Abstract) Proc. South. Weed Sci. Soc. 28:364-265.

Williams, R.D., P.C. Quimby, Jr., and K.E. Frick. 1976. Intraspecific competition in purple nutsedge. (Abstract) Proc. South. Weed Sci. Soc. 29:415.

Frick, K.E. and P.C. Quimby, Jr. 1977. Biocontrol of purple nutsedge by Bactra in a greenhouse. Weed Sci. 25:13-17.

Quimby, P.C., Jr., E.B. Hollingsworth, and R.L. McDonald. 1977. Techniques for greenhouse evaluation of herbicides on saltcedar. Weed Sci. 25:1-4.

Frick, K.E. and P.C. Quimby, Jr. 1976. Greenhouse studies related to the biocontrol of purple nutsedge by Bactra. (Abstract) Abstr. Weed Sci. Soc. Am.:59.

Quimby, P.C., Jr., J.R. Potter, and J.D. Tallant. 1976. Comparative growth of five amphibious weeds. (Abstract) Abstr. Weed Sci. Soc. Am.:42.

Quimby, P.C., Jr. and S.H. Kay. 1976. Alligatorweed and water quality in two oxbow lakes in the Yazoo River Basin. (Abstract) Suppl. J. Miss. Acad. Sci. 21:13.

Quimby, P.C., Jr., J.R. Potter, S.O. Duke, and S.H. Kay. 1977. Physiological aspects of anoxic quiescence in alligatorweed. (Abstract) Abstr. Weed Sci. Soc. Am.:61.

Quimby, P.C., Jr., K.E. Frick, R.D. Wauchope, and S.H. Kay. 1977. Effects of iron deficiency and cadmium on two biocontrol insects and their host weeds. (Abstract) Abstr. Weed Sci. Soc. Am.:60-61.

Frick, K.E., R.D. Williams, and P.C. Quimby, Jr. 1977. Effects of Bactra verutana and intraspecific competition on the growth of purple and yellow nutsedge. (Abstract) Abstr. Weed Sci. Soc. Am.:78.

Williams, R.D., P.C. Quimby, Jr., and K.E. Frick. 1977. Intraspecific competition in purple nutsedge. Weed Sci. 25:(In press).

Quimby, P.C., Jr. and S.H. Kay. 1977. Hypoxic quiescence in alligatorweed. Physiol. Plant. 40:163-168.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978-795-767/385